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PRELIMINARY LIGHTNING CLIMATOLOGY STUDIES FOR IDAHO

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PAGE

PRELIMINARY LIGHTNING CLIMATOLOGY STUDIES FOR IDAHO

ABSTRACT

Two years of cloud-to-ground lightning strike data from the Bureau of Land Management's Automatic Lightning Detection System are used to develop a preliminary thunderstorm climatology for the State of Idaho. The preliminary results suggest earlier climatologies based on widely separated weather observing stations underestimate the number of thunderstorm days in the region. Map types are then used to investigate the variations in the frequency of lightning under differing mid-tropospheric flow patterns. Finally, manually reported lightning activity levels are compared to lightning occurrence and density as measured by the automated system.

PRELIMINARY LIGHTNING CLIMATOLOGY STUDIES FOR IDAHO

I. INTRODUCTION

In 1983, the National Weather Service (NWS) Western Region began utilizing cloud-to-ground lightning strike information from the Bureau of Land Management's (BLM) detection network. Since the original description by Rasch and Mathewson (1984), significant changes have been made to both the NWS and BLM programs. Most notably, the BLM has increased the number of sensors, added the capability to differentiate between positive and negative strikes, and extended the program to year-round operation. The NWS now processes and archives the lightning data at the NWS Forecast Office in Boise, Idaho, since the facility is co-located with the BLM computers. The programs of these two agencies came to maturity in 1985. As a result, the data sets for 1985 and 1986 are almost 100 percent complete. These two years of data were used to develop a preliminary thunderstorm climatology for the Idaho area, investigate lightning occurrence under various mid-tropospheric flow patterns, and compare BLM and U.S. Forest Service (USFS) manually reported lightning activity levels (LAL's) with actual lightning occurrence.

II. PRELIMINARY THUNDERSTORM CLIMATOLOGY

Until now, thunderstorm climatologies have been based on the only available source, surface weather observations. Unfortunately, the western United States in general and Idaho in particular have few surface weather observing sites. In addition, the region is largely mountainous, and the few observation sites that do exist are in valleys. This has led to what appears to be a significant underestimation of the frequency of thunderstorm activity.

An early example of thunderstorm climatology is shown in Figure 1 from Climate and Man (1941). Based on 40 years of data the climatology depicts the average annual number of thunderstorm days varying from somewhat less than 20 days in western Idaho to a little more than 40 days per year in eastern Idaho. Figure 2, from Critchfield (1966), portrays a significantly different climatology, with the area in eastern Idaho which was a maximum in Figure 1, now depicted as a relative minimum. A maximum is analyzed over southwest Montana. Figure 3 from Changery (1981) is an attempt to utilize all available data and subjectively incorporate major terrain influences. This climatology depicts a relative minimum through the Snake River Valley of southern Idaho with maxima near the central Idaho-southwest Montana border and just east of Idaho in western Wyoming. A secondary maximum is also shown over the mountains along the Idaho-Utah border.

Since 1983, lightning strike data has been available from the BLM detection network and is transmitted to NWS computers at Boise in real time. Each strike is stored with its time of occurrence, latitude, longitude, signal strength and sign (positive or negative), number of return strokes, and which direction finders were used to locate the strike. This is done for the entire western United States. In 1985 a total of 1,913,602 strikes were recorded by the network. In 1986, 2,323,897 strikes were logged. For this study, the data was filtered into the grid block network illustrated in Figure 4. Each grid block is .5 degree latitude by .5 degree longitude and thus very close to the size used by Reap (1986) in the study of 1983-84 data. The grid is oriented differently than Reap's however. Our grid size was chosen for computer resource reasons and also to minimize the possibility of over-fitting the data based on current estimates of errors in specifying the location of a strike.

Since the BLM network was only operational for the months of April through October during 1985, those seven months of data were used for both 1985 and 1986 in constructing the preliminary climatologies. It appears that thunderstorms are quite rare in Idaho during the winter months of November to March. The authors do reserve the right to reverse their position on this after a few years of data have been assembled. In any event, current exclusion of these months may cause a slight underestimation of the "annual" frequencies found.

Figure 5 depicts the average annual number of lightning days based on the 1985 and 1986 BLM data. Stippling on the figure denotes generalized "mountainous" terrain. General valley areas are the Snake River Valley of southern Idaho and the Idaho Panhandle region. It should be noted that the Snake River Valley actually slopes from 600 meters near the western Idaho border to 1500 meters at its northeastern extension. Figure 5 indicates a general increase in the frequency of lightning days from west to east across the state. This trend appears to be definitely distorted by topography. Note that a relative minimum pushes eastward across the Snake River Valley while a relative maximum extends westward along the mountains near the state's southern border.

Comparison of Figure 5 with Figures 1 through 3 indicate two striking differences. First, this preliminary climatology suggests a significantly greater frequency than previously thought. Second, the maximum presented by Changery in Figure 3 appears to actually be further southeast and centered over the Yellowstone National Park area. The absolute maximum appears to occur over the mountains just east of the northern extension of the Snake River Valley. Interesting secondary maxima also appear to exist over the southwest Idaho mountains and the Wallowa Mountains in the northeast corner of Oregon.

As indicated by the values given for the total number of strikes recorded by the BLM network for the two years used, 1986 appears to have been a much more active thunderstorm year. This was true for our grid as well. In 1985 a total of 196,474 strikes fell within the grid. During 1986 the total was 262,809. Figure 6 depicts the number of lightning days for just 1985. Figure 7 is for 1986 alone. Comparison of these two figures indicates a difference in the number of days each year. However, the regions of relative maxima and minima coincide almost exactly. This lends strong credence to the hypothesis of terrain-induced convection. However, terrain height does not appear to be the dominant factor.

Figure 8 depicts the average number of hours with lightning strikes per year. Again the pattern coincides quite well with the pattern of lightning days across the state. When one looks at the average number of actual lightning strikes per year as shown in Figure 9, a significantly different pattern emerges. The region around Yellowstone which stood out as a center of maximum lightning days and hours now appears as a relative minimum. When considering total lightning strikes, the absolute maximum shifts to near the southeast corner of Idaho. Caution must be exercised in drawing conclusions from this, however, as operational experience has shown that occasionally a thunderstorm can become extremely active with regard to the amount of cloud-to-ground lightning it produces. The analysis does suggest that these highly active thunderstorms may be quite rare over some locations and show a preference for other areas.

III. FREQUENCY OF LIGHTNING UNDER VARIOUS SYNOPTIC FLOW PATTERNS

Figure 10 portrays the two year average percent of days with lightning for the summer season of June, July and August. As can be seen, the summer season climatological probability of a day with lightning varies from less than 20 percent over much of western Idaho to 50 percent in the Upper Snake River Plain, the Yellowstone area and over the Teton Range.

To test whether the frequency of lightning days varies significantly under different synoptic scale flow patterns, the two year summer season data were stratified based on the 500 mb map types developed by Rasch and MacDonald (1975). The 1200 GMT 500 mb geopotential height analysis for each of the 184 sample days was assigned to the summer map type that it correlated with best. Figures 11 through 20 depict each of the 10 map types along with the corresponding frequency of occurrence of lightning during the period 1800 GMT to 0600 GMT (noon to midnight) on those days. Thus each figure gives the probability of lightning for each grid block under the accompanying synoptic scale mid-tropospheric flow pattern.

Figure 11 gives the Summer Type 1 flow pattern and corresponding probability of lightning. As with the data used to develop the map types, type 1 cases made up the largest percentage of the two year sample used in this study. Type 1 is a weak zonal pattern that occurs over the western United States frequently during the summer months. Thus, as expected, the Type 1 frequencies are very similar to the seasonal mean frequencies shown in Figure 10. The probabilities over the southern portion of the state are slightly higher and those over the north a little lower than the mean.

Summer Type 2 probabilities presented in Figure 12 indicate a marked deviation from the means of Figure 10. Type 2 cases are characterized by the axis of the strongest upper tropospheric winds over or just south of southern Idaho. Thus dynamics associated with the jet stream may account for the much higher than normal probabilities over southern Idaho. The cold core areas of low pressure aloft associated with Type 2 cases often tracks across northern Idaho. This may explain the increased probabilities over the Panhandle.

Map Type 3, with an upper ridge axis over or just east of Idaho, was the second most prevalent pattern in both the data set used to develop the map types, and for 1985, 1986. The corresponding probability of lightning chart in Figure 13 is even closer to the seasonal climatological probability than Type 1. Main differences are more of a minimum in the Snake River Valley and a stronger maximum over the Wallowa Mountains of northeast Oregon.

Map Type 4 shown in Figure 14 is characterized by a strong upper ridge near 100 degrees west longitude and a fairly deep trough on or just off the West Coast. The jet stream axis is usually, but not always, north and west of Idaho. In some cases the upper flow over Idaho, especially the southern portion, is very weak. This pattern can be quite moist. The corresponding probability chart reflects this with a relatively high occurrence of lightning over the Snake River Valley.

Figure 15 shows Type 5 which is characterized by a split flow or a shearing trough over the state. The associated lightning probability chart suggests the troughs in the northern branch of the split are generally dry until they interact with the usually more moist weak southerly flow over southeast Idaho and western Wyoming.

Map Type 6, shown in Figure 16, is also characterized by a split flow. In this case the flow over Idaho is northwesterly. As expected, the corresponding lightning activity is quite low over most of Idaho under this pattern. In the light flow aloft over Montana, lightning episodes are more frequent.

The dominant feature for Type 7 days is a short wave ridge moving over Idaho in the wake of a trough. As shown in Figure 17, thunderstorm activity is well below the climatological frequency over the entire region for this type of flow pattern.

Probabilities are also quite low for Type 8 as shown on Figure 18. The glaring exception is the intriguing high frequency area over Yellowstone Park. The anomaly suggests that the terrain of that area may somehow react very favorably with short waves moving south in the northerly flow. There were only 17 Type 8 cases so it is not possible to say whether or not the anomaly is a stable one.

Map Type 9 in Figure 19 is an even rarer occurrence, comprising about one-half of one percent of all the cases used to construct the map types and about two percent of the 1985-1986 cases. The accompanying probability chart is only included for completeness. No real conclusions can be drawn from such a small sample size. However, as expected, the pattern does appear to produce considerable thunderstorm activity over Idaho.

Map Type 10 as depicted in Figure 20 is dominated by a broad ridge of high pressure over the western United States. The winds over Idaho are extremely light. Thus this map type may be an excellent starting point in investigating how mountainous terrain modifies the distribution of so-called "air-mass" thunderstorms. The associated lightning probability chart suggests that a few additional years of data may in fact provide some concrete insight into this problem. Note the numerous maxima and minima in Figure 20. These appear to generally correspond with significant terrain features. Equally important, if one compares Figure 20 with the more dynamic types 2 and 4, these "air-mass" centers generally tend to correspond to "dynamic" centers of the opposite sign.

IV. MANUALLY OBSERVED LIGHTNING ACTIVITY LEVEL

The National Fire Danger Rating System (NFDRS) implemented in 1972 is a computer model used by all federal and many state land management agencies to calculate current and forecast fire potential. In the western United States, lightning is the greatest single cause of forest fires. A critical element used to determine fire danger in the NFDRS is a lightning risk factor.

Prior to the introduction of the NFDRS, lightning forecasts were in probability terms. This approach made verification difficult. Studies of lightning and fire starts during Project Skyfire (1969) and later studies by Fuquay (1980) lead to the lightning activity level (LAL) index used by the NFDRS.

The LAL is a numerical rating which ranges from 1 to 6. It is keyed to the frequency and characteristics of the cloud-to-ground lightning observed or forecast for a specified area and time period. The scale is exponential in powers of 2. Beginning with LAL 2, each succeeding level through LAL 5 represents twice the cloud-to-ground lightning activity as the previous level. LAL 6 is a special and rare case in which high level dry thunderstorms create severe fire problems. LAL 1 indicates no lightning during the specified rating period.

Several schemes have been devised to help the fire weather observer and fire weather forecaster determine the appropriate LAL category. The Lightning Activity Guide (Deeming 1978) is the standard by which the LAL is presently calculated. The Guide has been divided into two sections. The first uses cloud descriptions and precipitation conditions to estimate the LAL category. The second uses lightning rates and amount estimates to arrive at a representative LAL category. The basic unit of area represented by a LAL is 2,500 square miles. This is accepted as the largest area that lightning activity can be effectively observed from a surface observation point such as a fire lookout. It roughly corresponds to a circle around the observation site with radius of about 45 km.

The observer subjectively assigns a LAL value. The ALDS network now provides the opportunity to compare these subjective reports with actual lightning occurrence. For this comparison 18 observation points in the Boise Fire Weather District were chosen. These 18 locations correspond to the established verification stations in each fire weather forecast zone as shown in Figure 21. Two summers (1985, 1986) of data were available for these comparisons.

Figure 22 shows the relative frequency distribution of LAL 2 through LAL 6 upon which the NFDRS is based. Also shown is the frequency distribution of the manually reported LAL for the 18 sites during the two year study period. As Figure 22 indicates, the manual LAL's were highly weighted toward the lower LAL categories. The frequency dropped off rapidly in the higher categories. This distribution is far from the frequency distribution the NFDRS expects, i.e., emphasis on the middle categories.

For each day, an ALDS LAL was assigned to each observation site. This was done by computing the total number of cloud-to-ground lightning strikes which fell within a 45 km radius of the observation site and then using the lightning density limits established for each LAL category by the NFDRS. For example, if 40 lightning strikes were recorded within 45 km of a station, a "true" LAL of 3 was assigned since the NFDRS range for LAL 3 is 11 to 50 strikes in a 24-hour period. Table 1 shows the percentage of correct manual observations as verified by the ALDS data. As shown, the frequency of correct categories during thunderstorm days is generally 50 percent or less. The only category which shows a high degree of skill is LAL 5. This is probably due to the fact that this category has the widest limits. Also, the station (Malad) which contained the bulk of LAL 5 cases was near the lightning maximum for the region as indicated in Figure 9. The LAL 1 category should be considered independently since it represents days with no thunderstorms. Table 1 indicates that observers totally missed 28 percent of the lightning occurrences the past two summers. The table also shows that only reported LAL categories 1 and 5 were generally representative of the actual lightning density that occurred.

A look at the means, standard deviations, and ranges of true lightning densities (ALDS data) corresponding to the manually reported LAL's is shown in Table 2. The means for each category are significantly higher than the established NFDRS limits (Table 3). Note also that the standard deviations and ranges are quite large and many overlap. Table 2 does indicate that a few observing sites were able to show skill in assigning LAL's which were representative of actual lightning density <u>in a relative sense</u>. Note, for example, the data for Stanley shows a general doubling of the lightning density mean value between LAL categories. The same is true for Mammoth and to some degree, Island Park.

Since the data from most observing sites showed very little correlation or apparent trends between the ALDS observed lightning densities and the manual reported densities (through the reported LAL), we investigated the possibility of adjusting the current NFDRS limits to improve the manually reported LAL verification.

The new limits shown in Table 3 we obtained by forcing the ALDS determined lightning densities for all 18 sites and all days into the NFDRS expected frequency distribution. As shown in Table 3 the data produced new limits which had lower bounds for all but categories 2 and 5. Also the ranges for categories 3 and 6 were greatly reduced while the limits for category 4 were significantly widened. When the manually reported LAL's were compared to the proposed new limits, the only category that experienced improvement was LAL category 4 as shown in Figure 23.

The frequency distribution of reported LAL's which the NFDRS expects to receive could be changed. This in turn might lead to better manually observed LAL verification scores by again utilizing the ALDS data to adjust the LAL category lightning density ranges. This "tampering" does not appear advisable, however, since it appears the problem lies not with the system, but with the manually reported LAL program.

V. DISCUSSION

The actual percentage of cloud-to-ground lightning strikes detected by the BLM network is still a matter of controversy. The most accepted figures vary from 50 to 75 percent. In addition, not all thunderstorms produce cloud-to-ground strikes as they pass over an area. Thus, one would expect a lightning days climatology, as presented here, to be a conservative estimate of thunderstorm days. However, the preliminary climatology suggests that previous climatologies significantly underestimate the frequency of days with thunderstorms over much of Idaho. It must be kept in mind, however, that the preliminary climatology presented is based on only two years of data. In addition, the grid block size used yields an effective "observer radius" of about 27 km which is somewhat larger than the radius of most human observations which are the basis for conventional thunderstorm climatologies.

The use of map types as a means of stratifying summer days and developing departures from the climatological frequencies appears promising. This approach could prove very useful in forecasting since the output from numerical models which verifies the best is mid-tropospheric synoptic scale geopotential height patterns. There are insufficient cases for a number of the map types to consider the current associated probability maps statistically stable, however. It also appears that the inclusion of an atmospheric stability or moisture parameter is needed to elevate the map type approach to a viable short-term detailed forecasting tool. In addition, we are looking at hourly frequencies to determine if there are preferred areas of initial thunderstorm generation. We also intend to decrease the grid block size to one-quarter of a degree which will give an effective "observer radius" of about 14 km to see if this reveals smaller scale terrain influences.

The portion of the study dealing with lightning activity levels points to serious flaws in the manual observations used by the NFDRS. Clearly the observer's bias towards the lower LAL's and the tendency for the observed categories to have a higher density singles out the current misunderstanding and shortcomings of the observational system. In the near future, the Boise Fire Weather Office will be developing an automatic LAL verification program using the lightning detection data and the current NFDRS limits. Since the LAL guide was developed before the advent of this more comprehensive observational tool, further climatological studies will be needed before a readjustment can be made to the NFDRS frequency distributions and lightning density limits.

VI. REFERENCES

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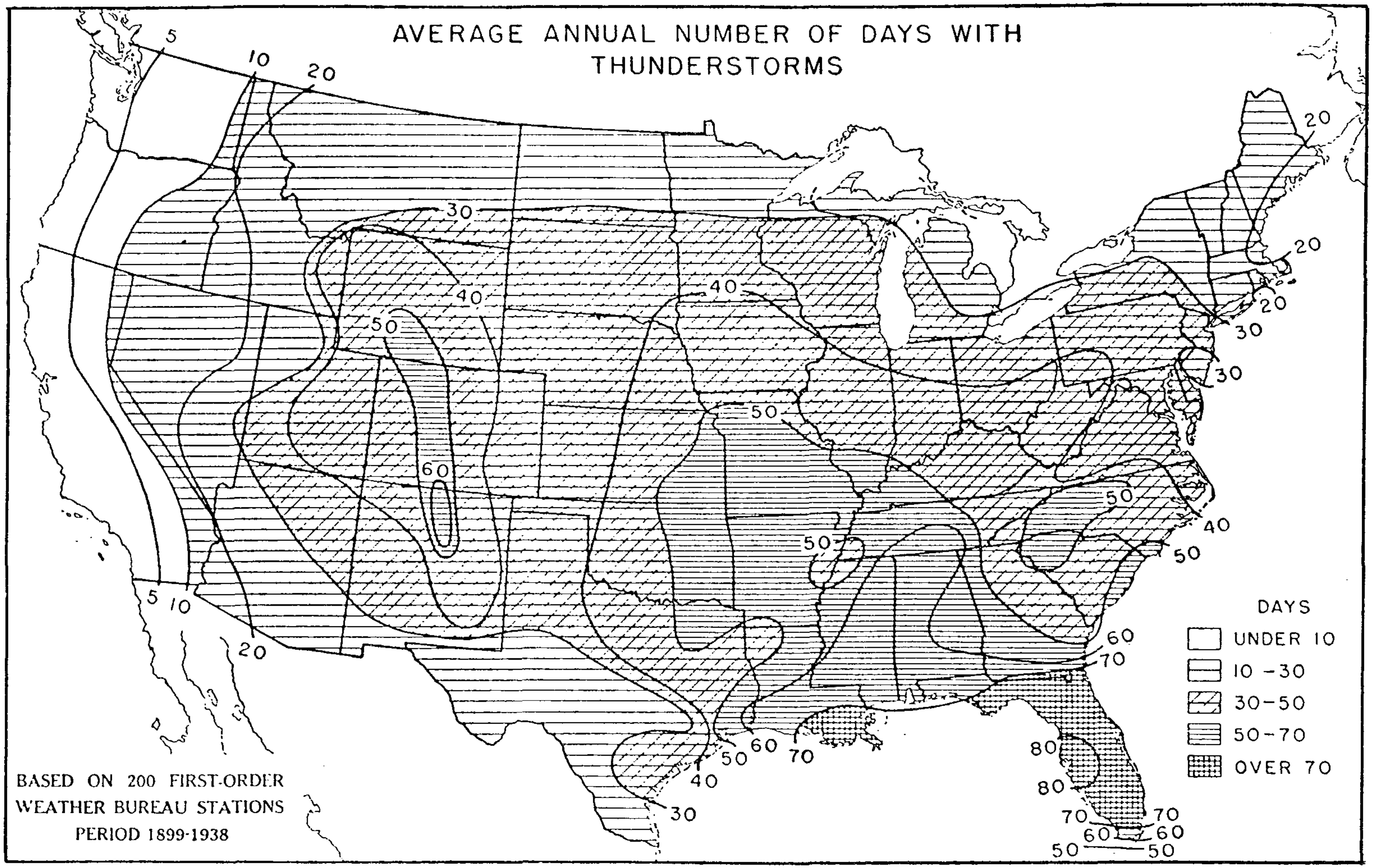


Figure 1. Average Annual Number of Days with Thunderstorms (from "Climate and Man", 1941)

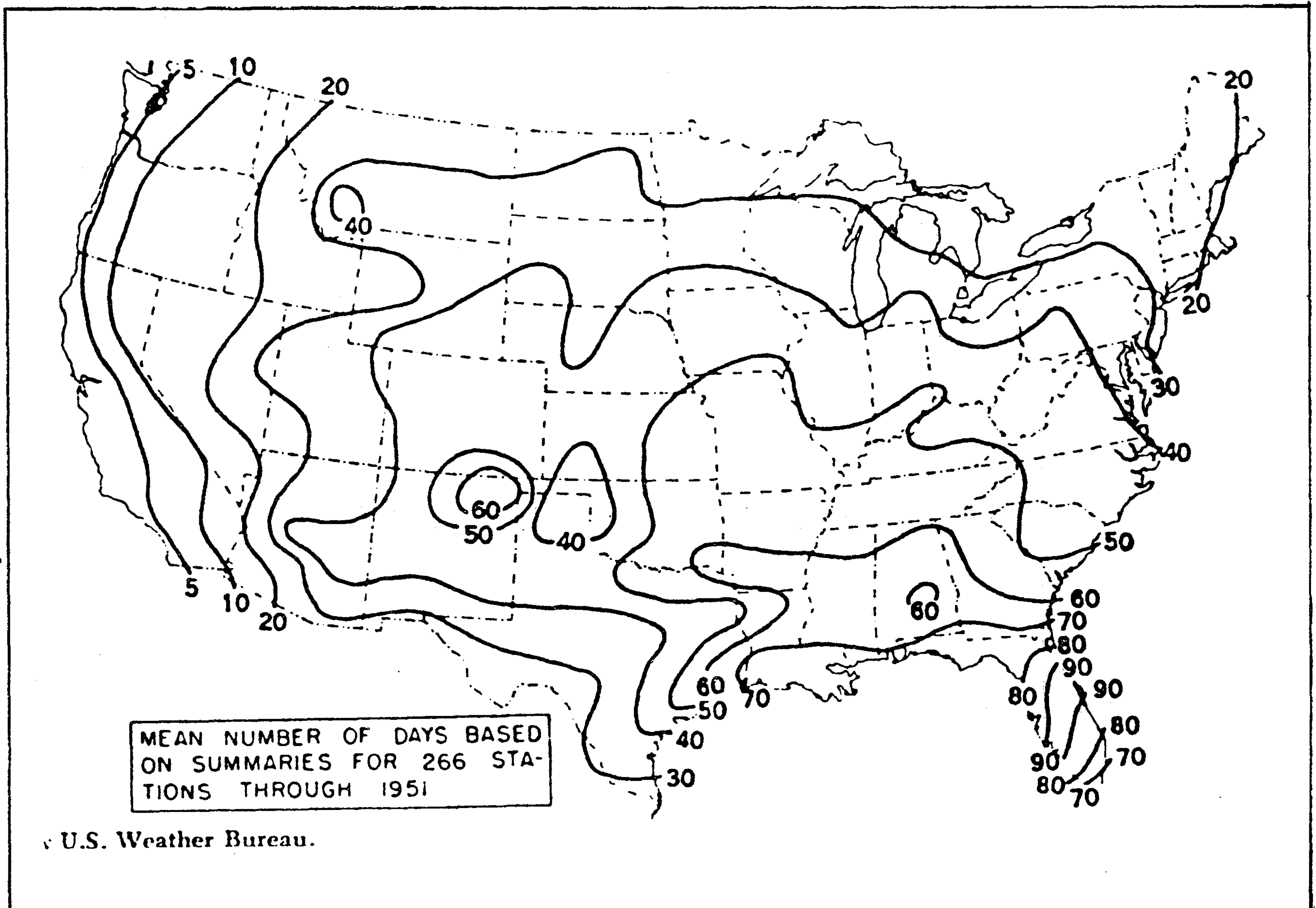


Figure 2. Average Annual Number of Days with Thunderstorms (from Critchfield, 1966).

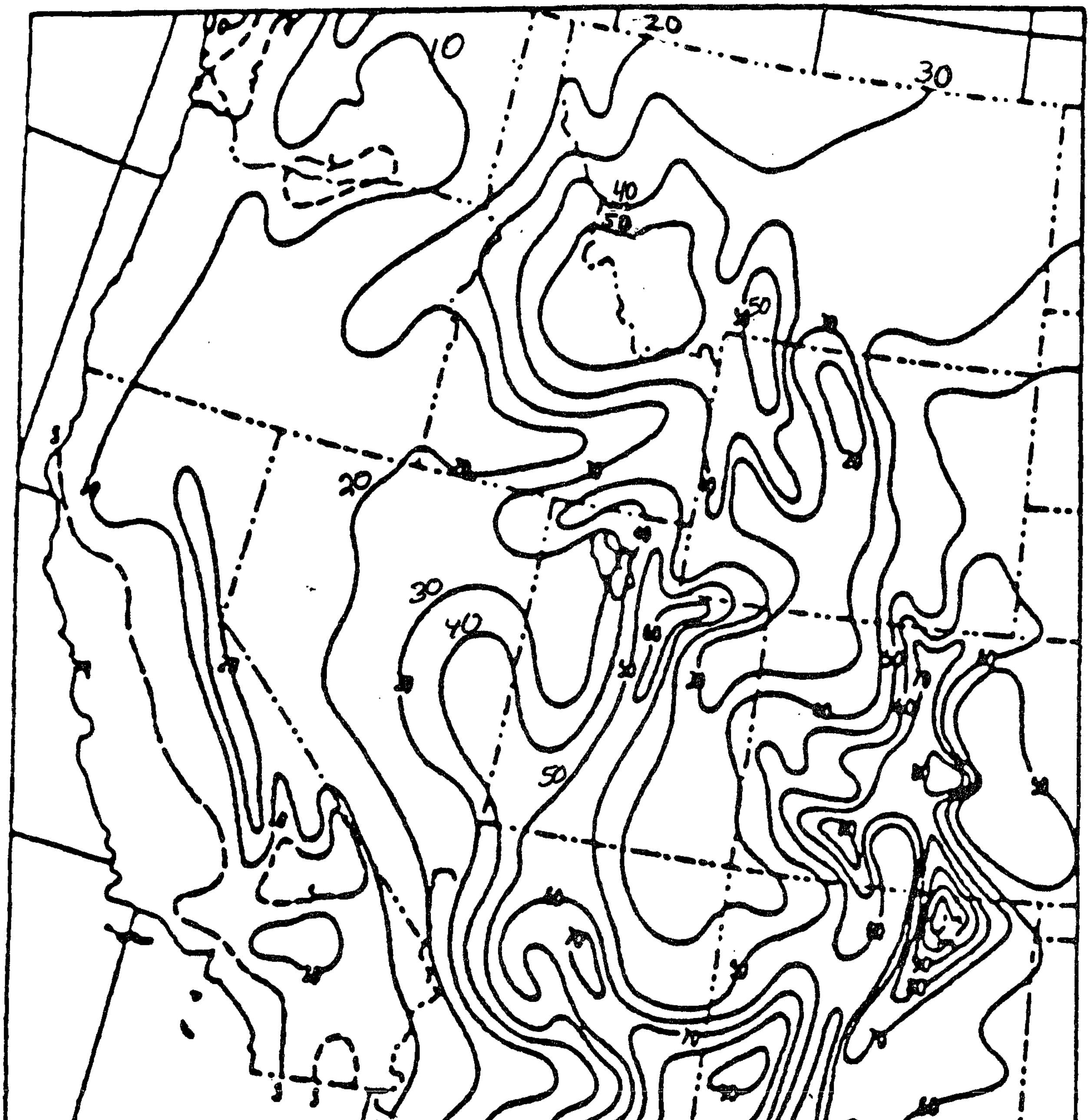
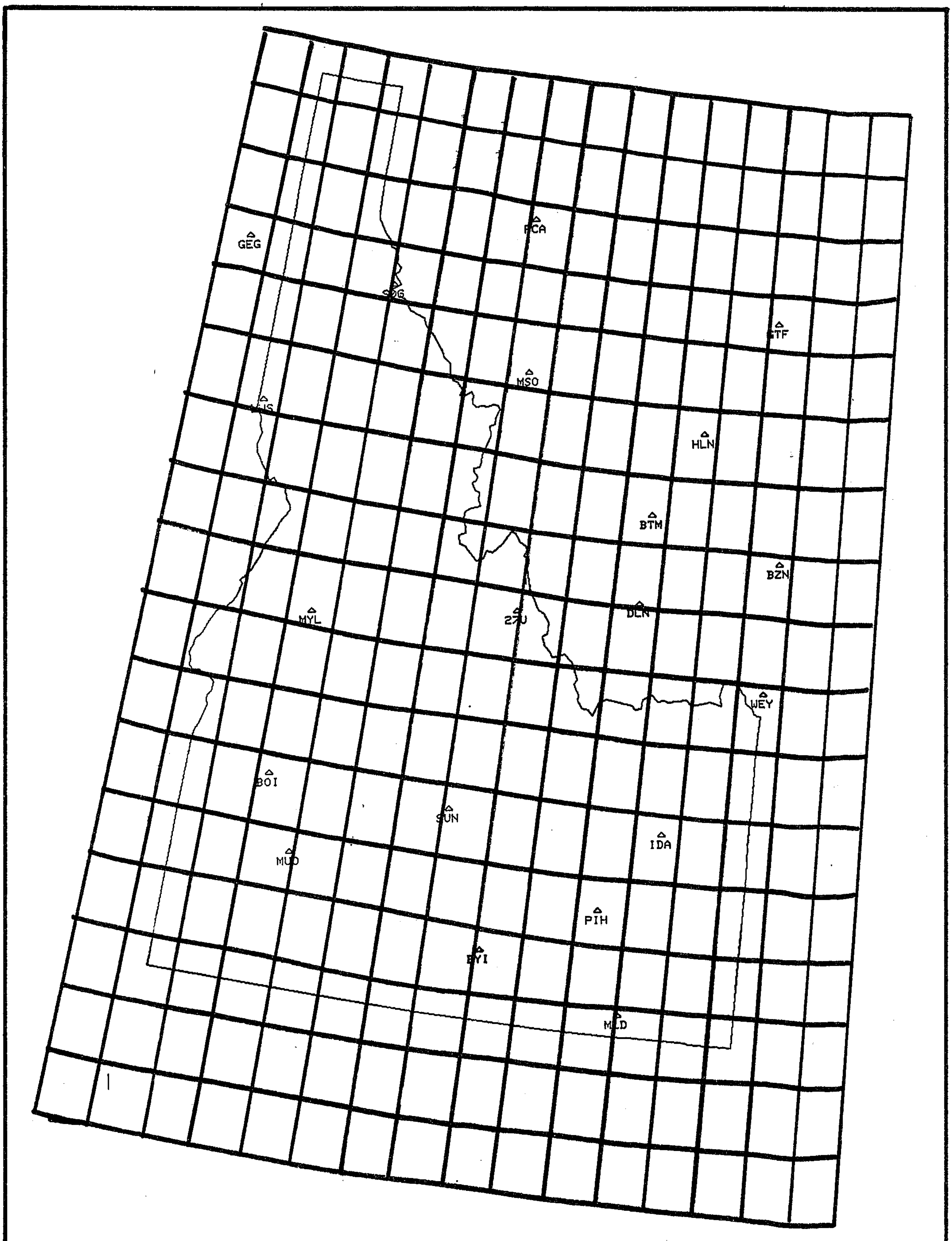


Figure 3. Average Annual Number of Days with Thunderstorms (from Changery, 1981).

Figure 4. Grid block (one-half by one-half degree) array for which lightning data is archived and analyzed.



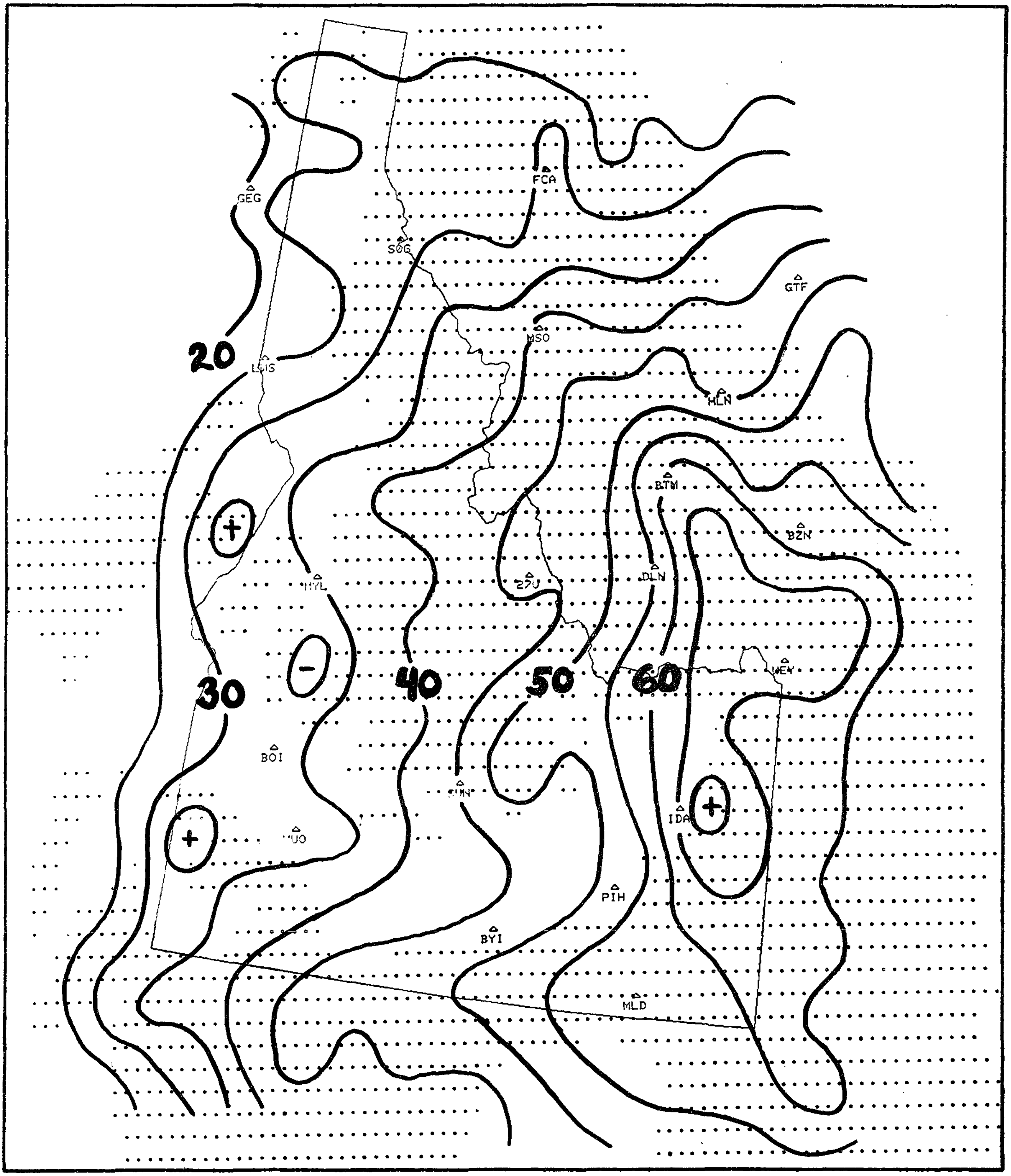


Figure 5. Average Annual Number of Days with Lightning Strikes based on two years (1985, 1986) of data.

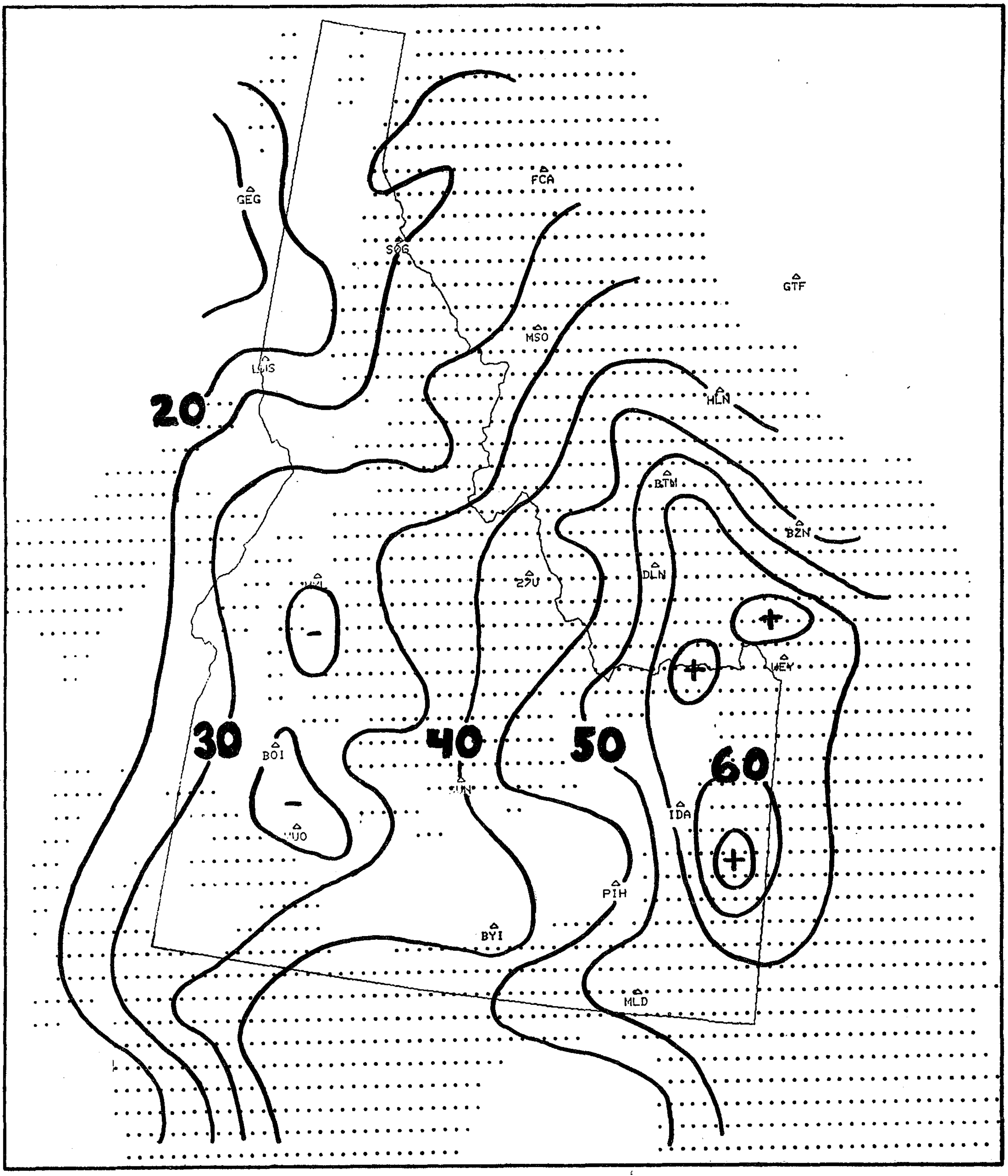


Figure 6. Number of Days with Lightning Strikes during 1985.

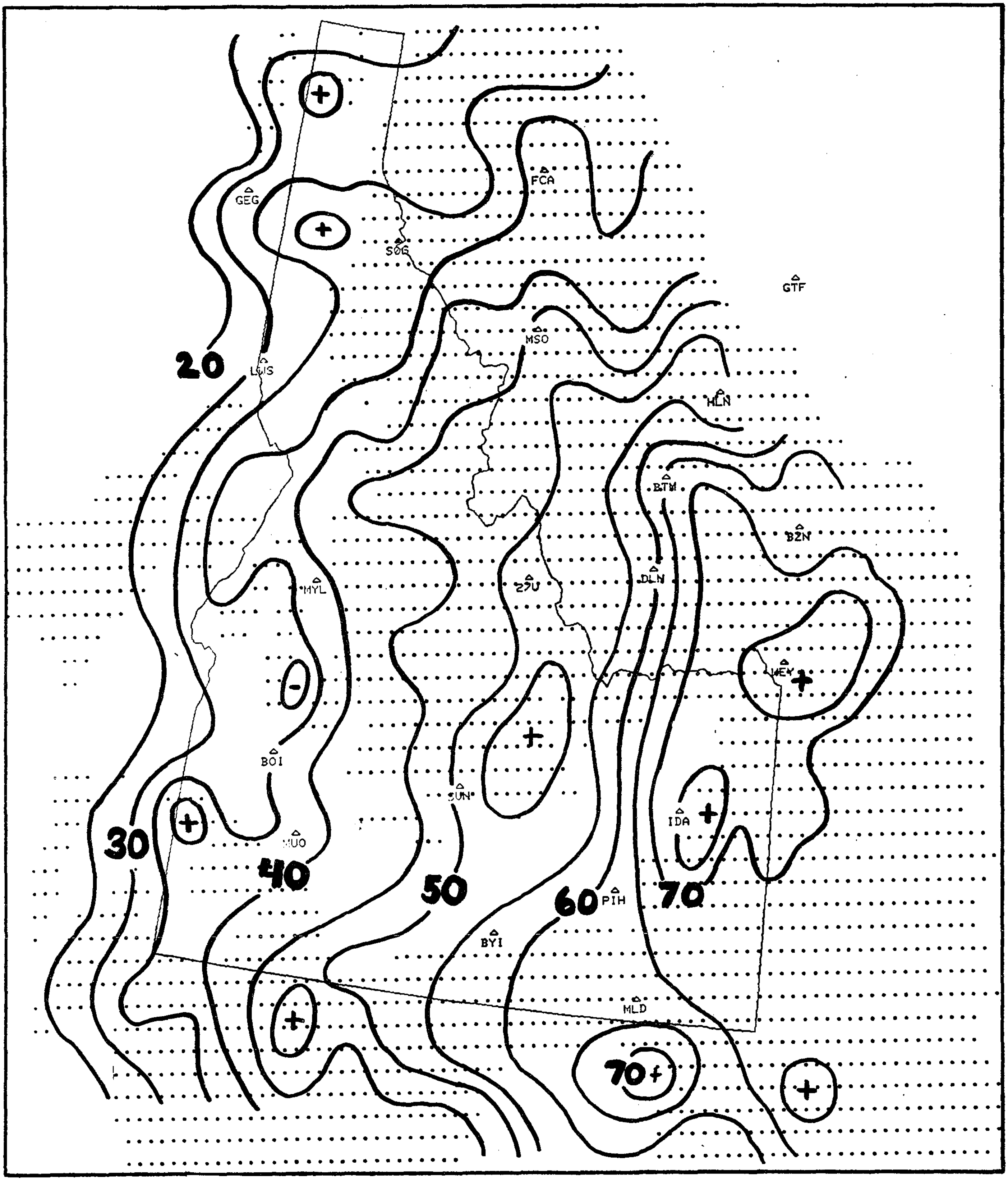


Figure 7. Number of Days with Lightning Strikes during 1986.

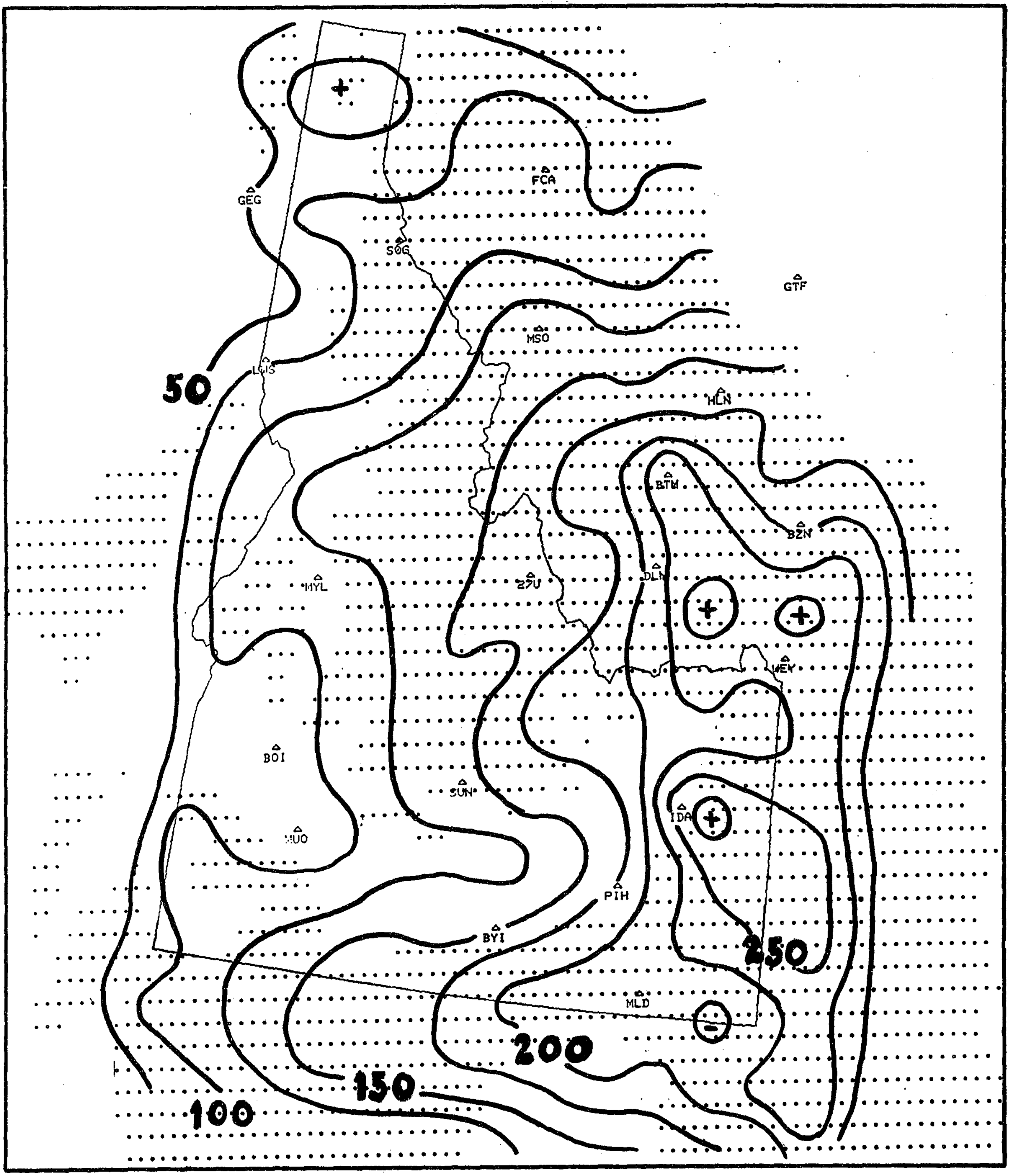


Figure 8. Average Annual Number of Hours with Lightning Strikes based on two years (1985, 1986) of data.

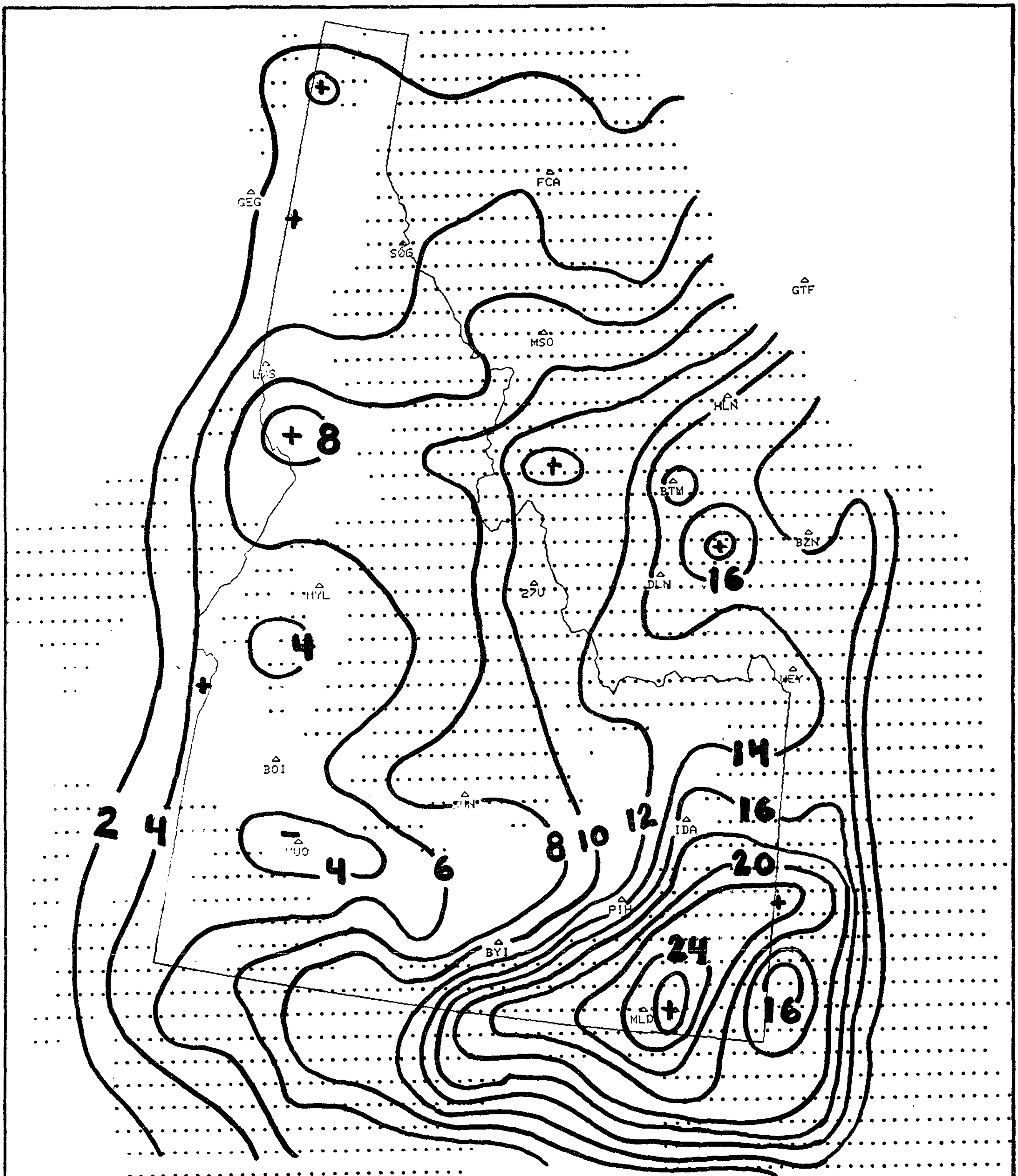


Figure 9. Average Annual Number of Lightning Strikes. Isoceraunics are labeled as 100's of strikes. Maximum value in southeast Idaho is 2644. Based on two years (1985,1986) of data.

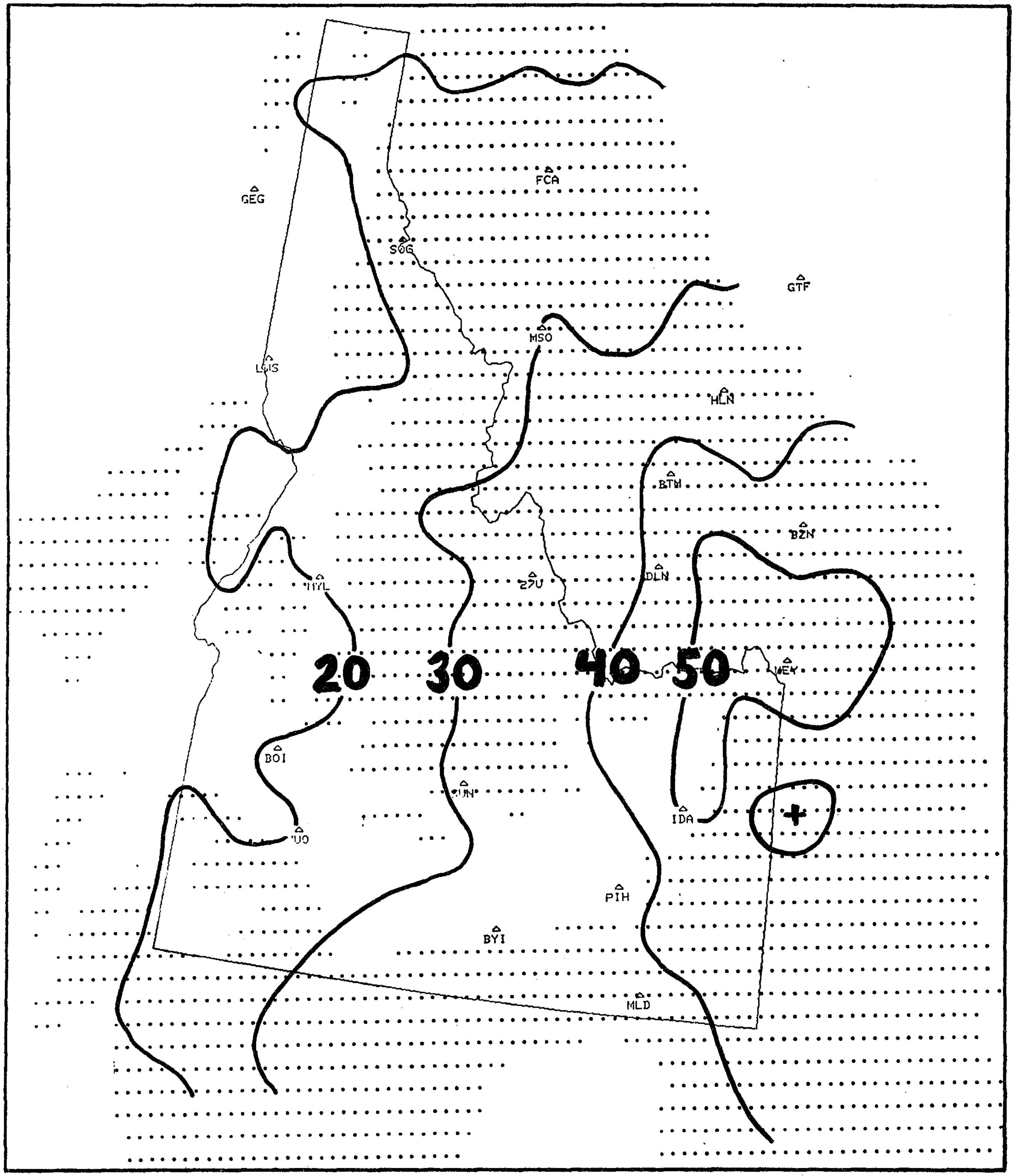


Figure 10. Average Annual Percent of Summer (June, July, August) Days with Lightning Strikes.

SUMMER TYPE I

00Z July 19, 1963
663 Cases

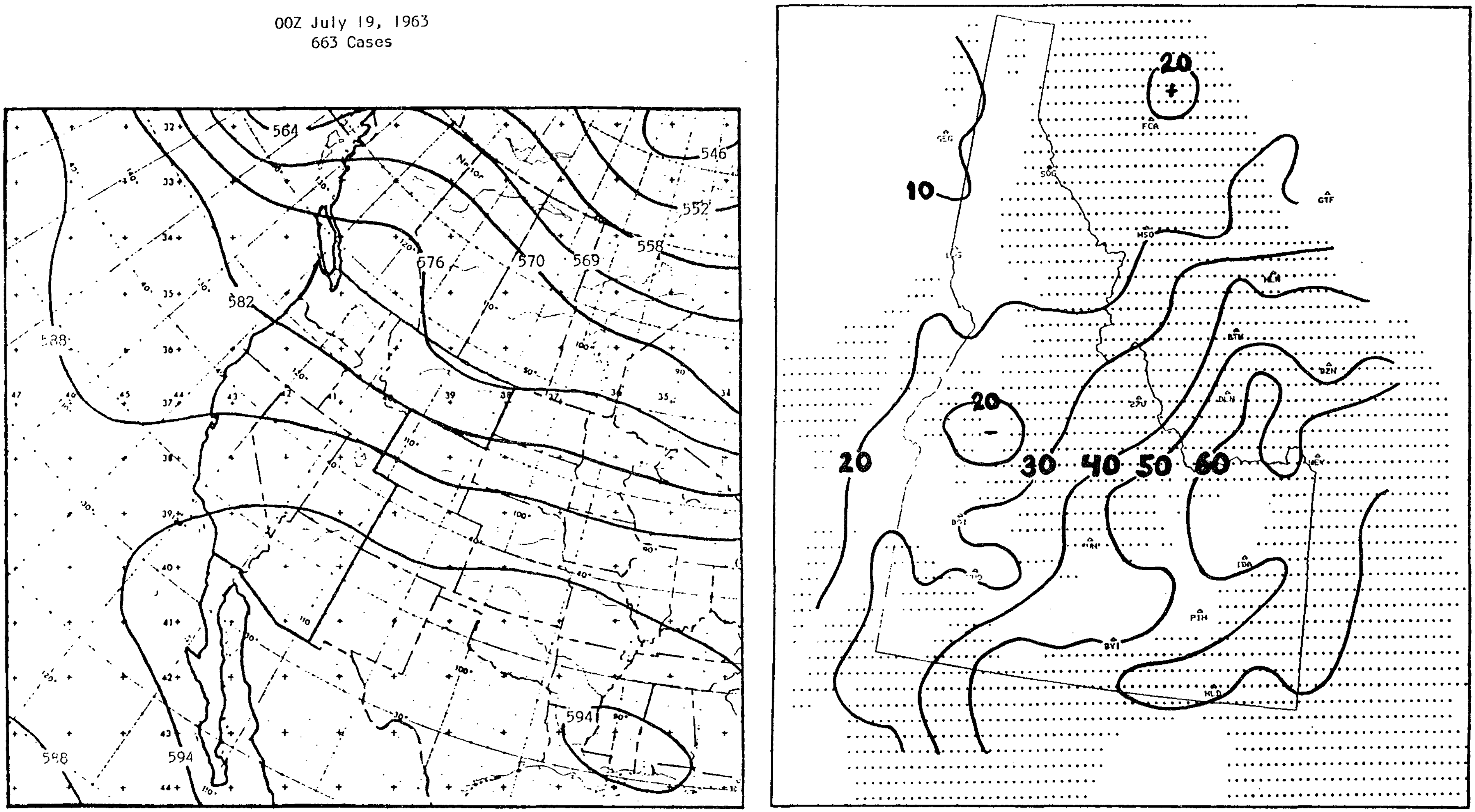


Figure 11. Summer Map Type 1 and Corresponding Percent Probabilities of Lightning during the period noon to midnight mdt. Probabilities based on 41 cases.

SUMMER TYPE 2

00Z June 22, 1963
78 Cases

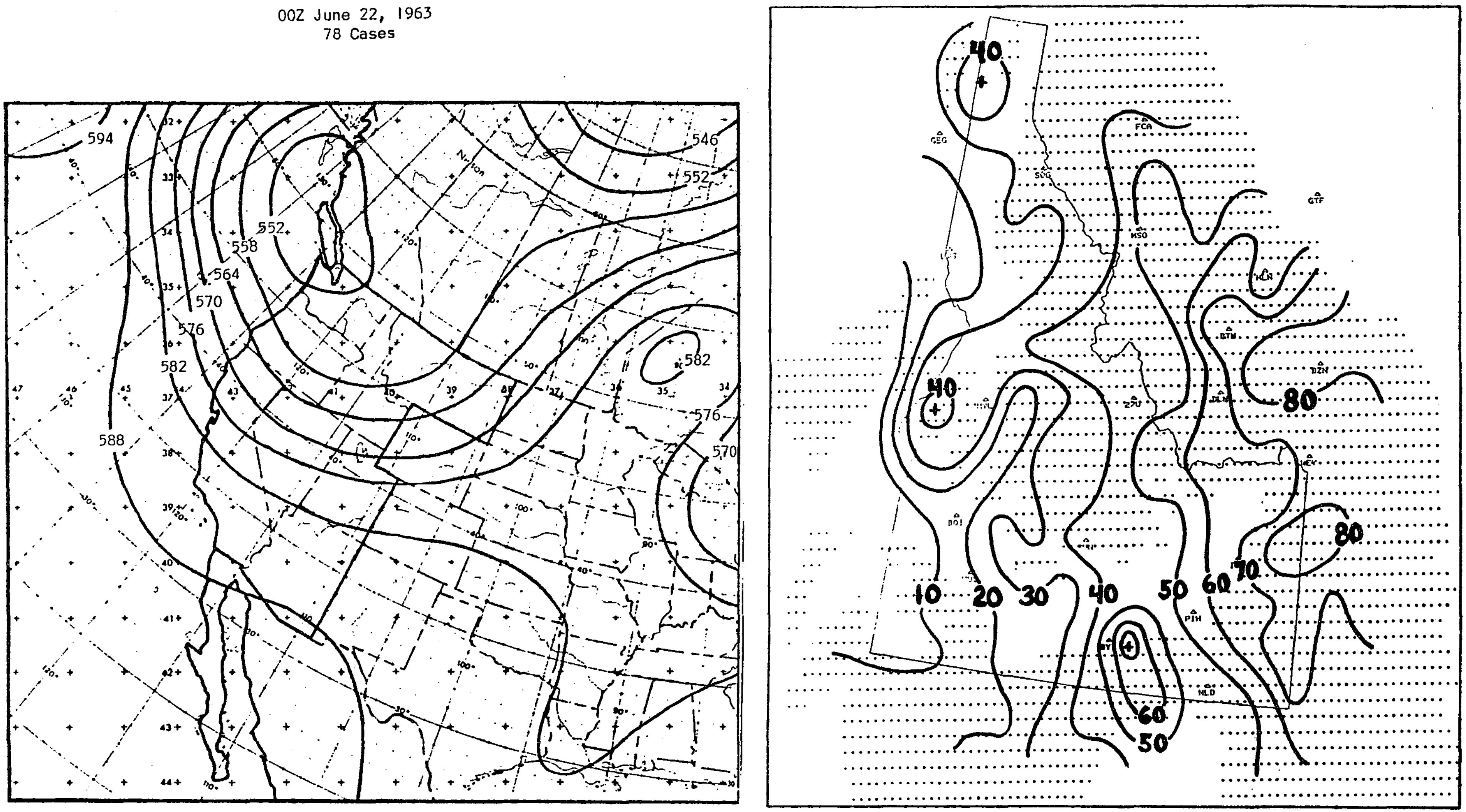
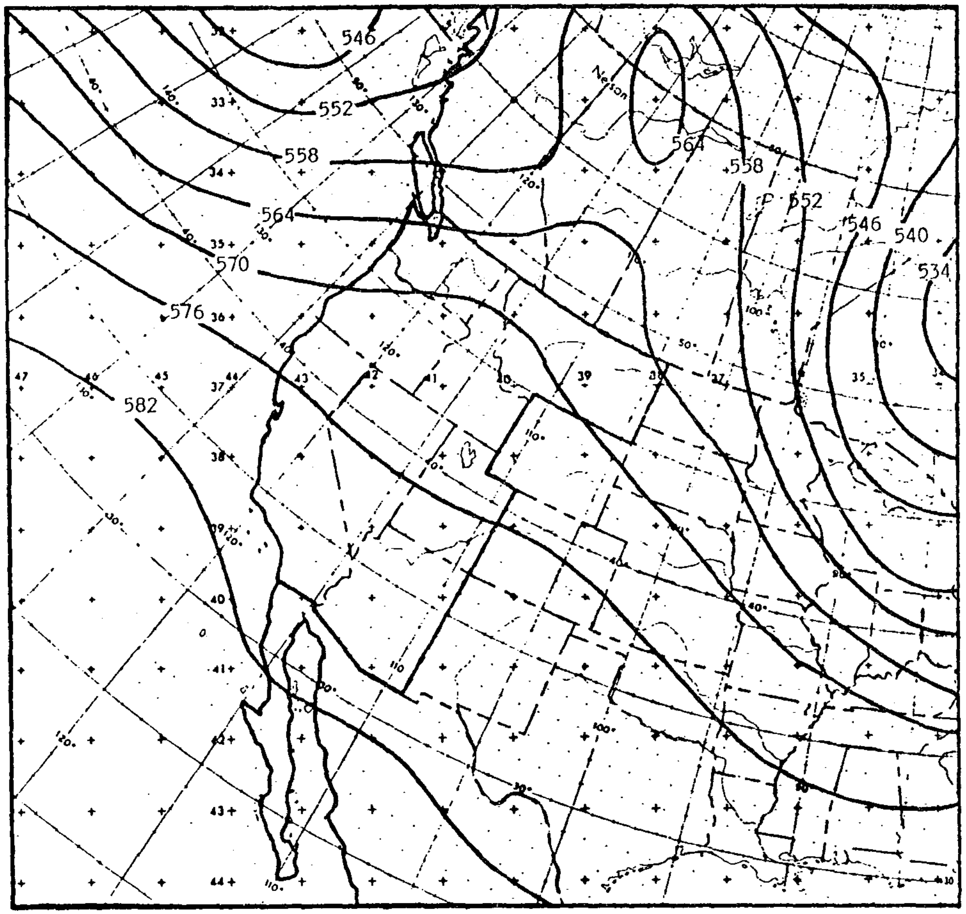


Figure 12. Summer Map Type 2 and Corresponding Percent Probabilities of Lightning during the period noon to midnight mdt. Probabilities based on 12 cases.

SUMMER TYPE 3

12Z June 3, 1964
135 Cases



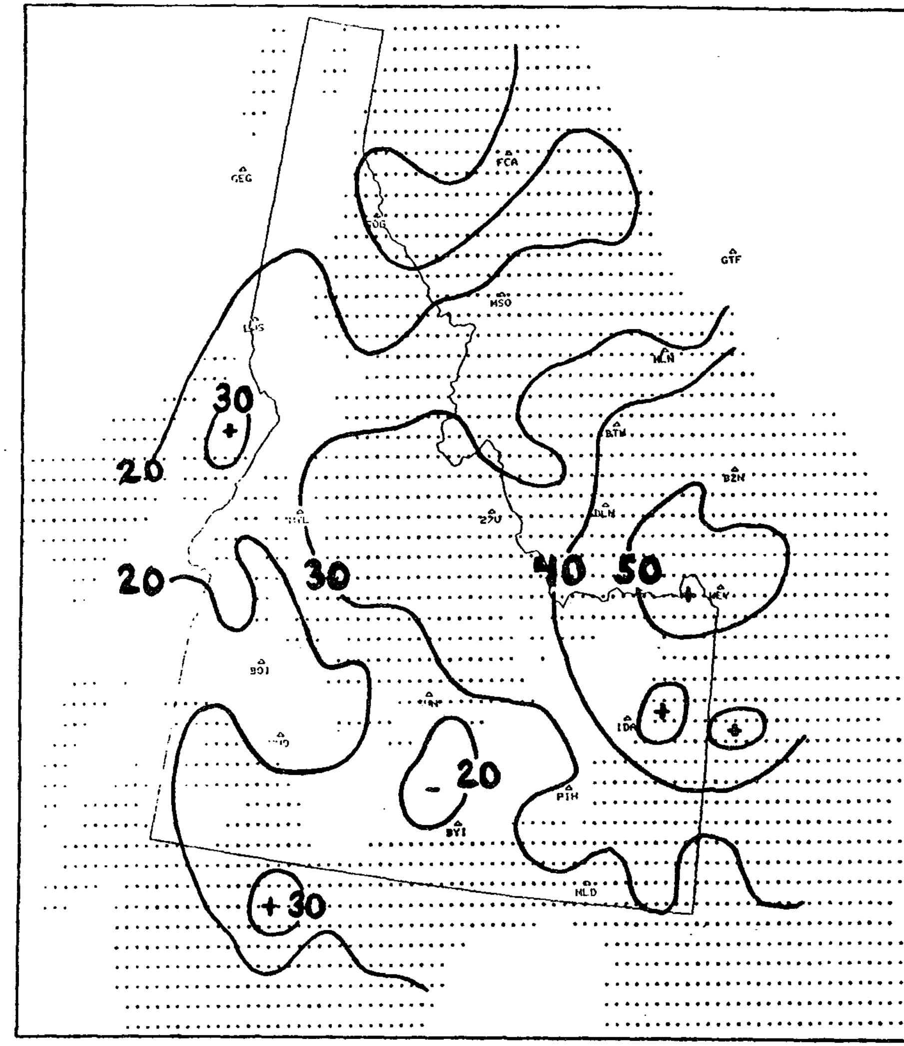
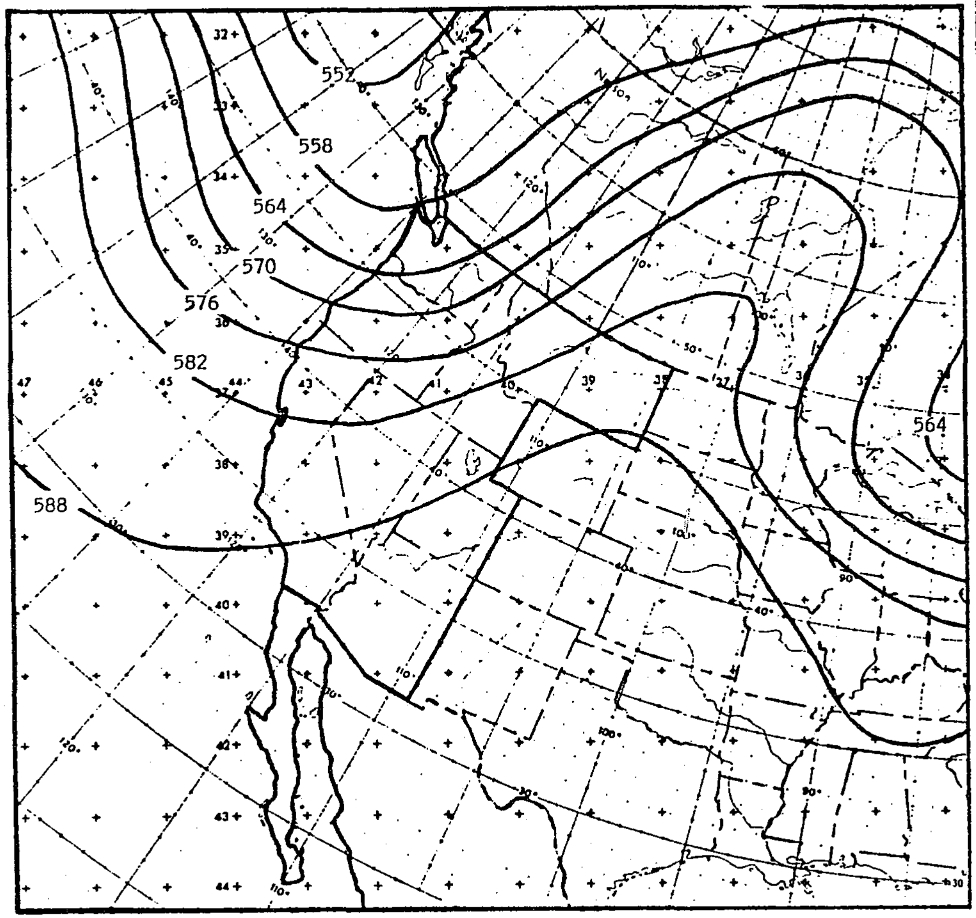


Figure 13. Summer Map Type 3 and Corresponding Percent Probabilities of Lightning during the period noon to midnight mdt. Probabilities based on 28 cases.

SUMMER TYPE 4

00Z August 26, 1968
86 Cases



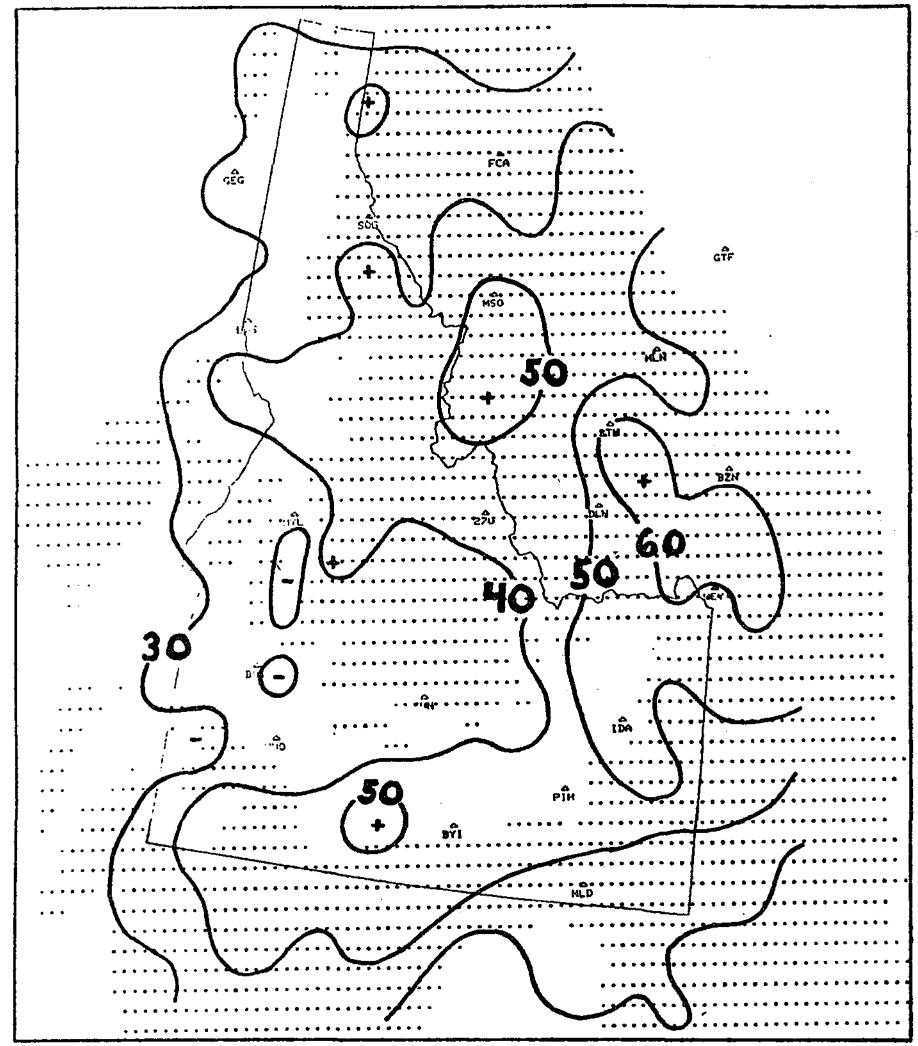


Figure 14. Summer Map Type 4 and Corresponding Percent Probabilites of Lightning during the period noon to midnight mdt. Probabilities based on 28 cases.

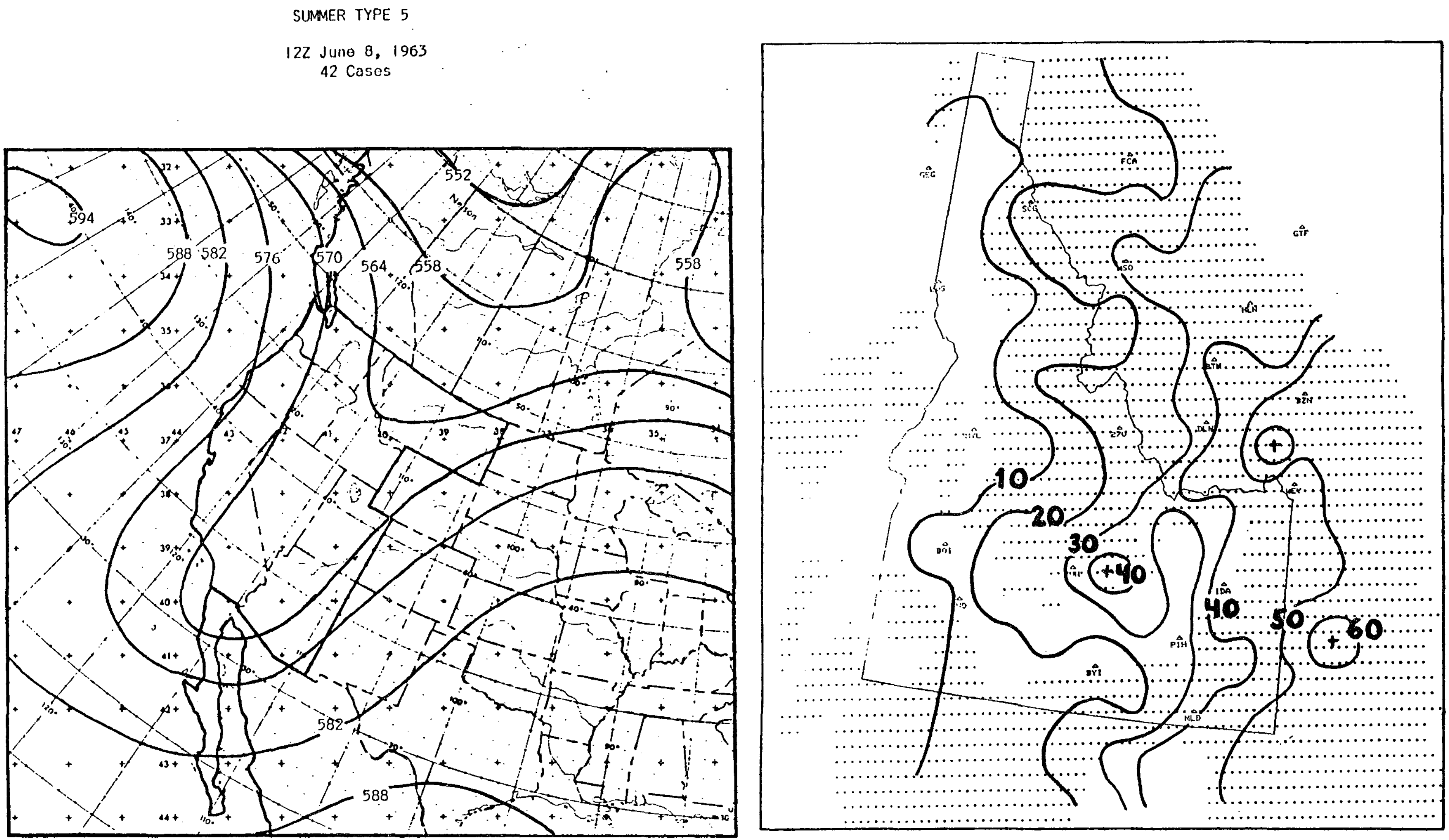
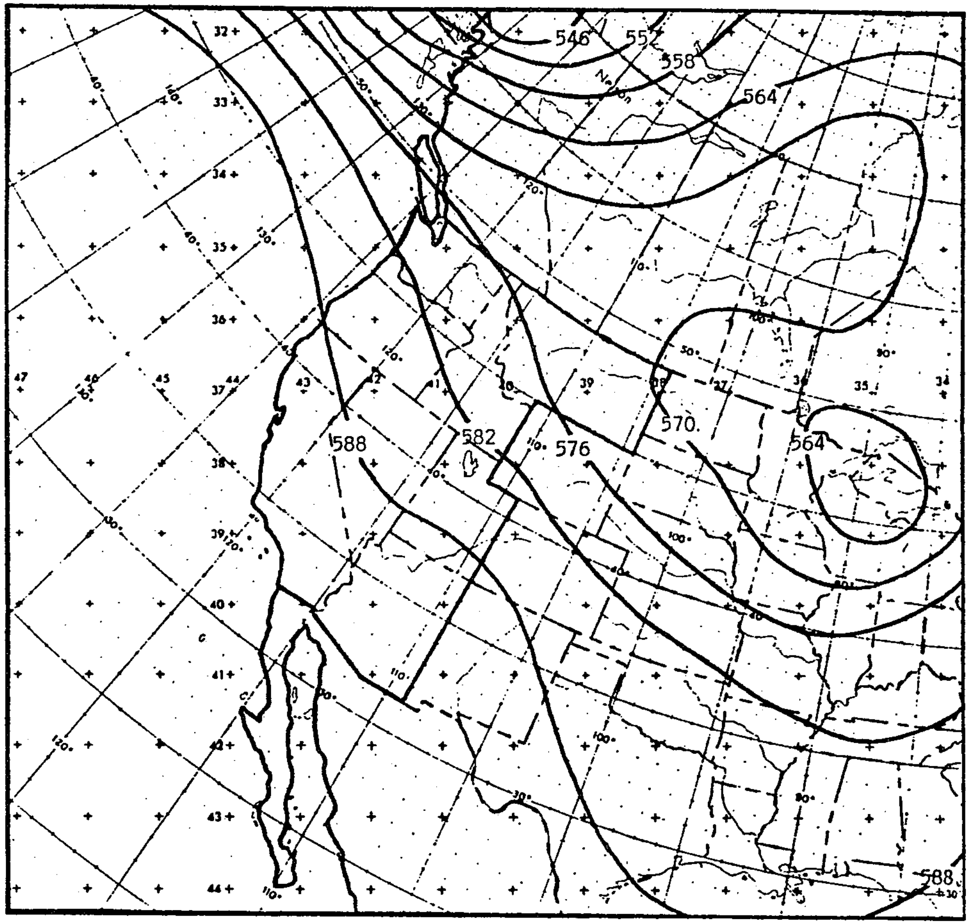


Figure 15. Summer Map Type 5 and Corresponding Percent Probabilities of Lightning during the period noon to midnight mdt. Probabilities based on 13 cases.

SUMMER TYPE 6

12Z August 9, 1966
60 Cases



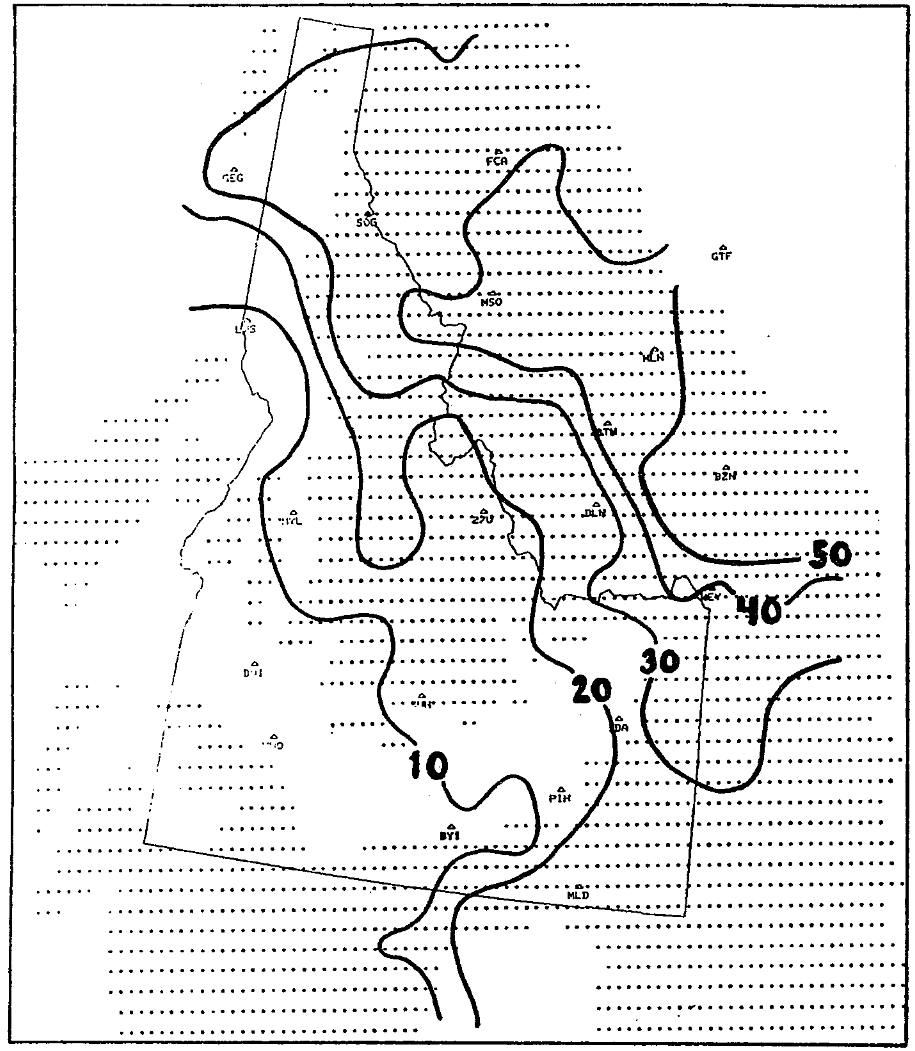


Figure 16. Summer Map Type 6 and Corresponding Percent Probabilities of Lightning during the period noon to midnight mdt. Probabilities based on 10 cases.

SUMMER TYPE 7

12Z June 10, 1968
52 Cases

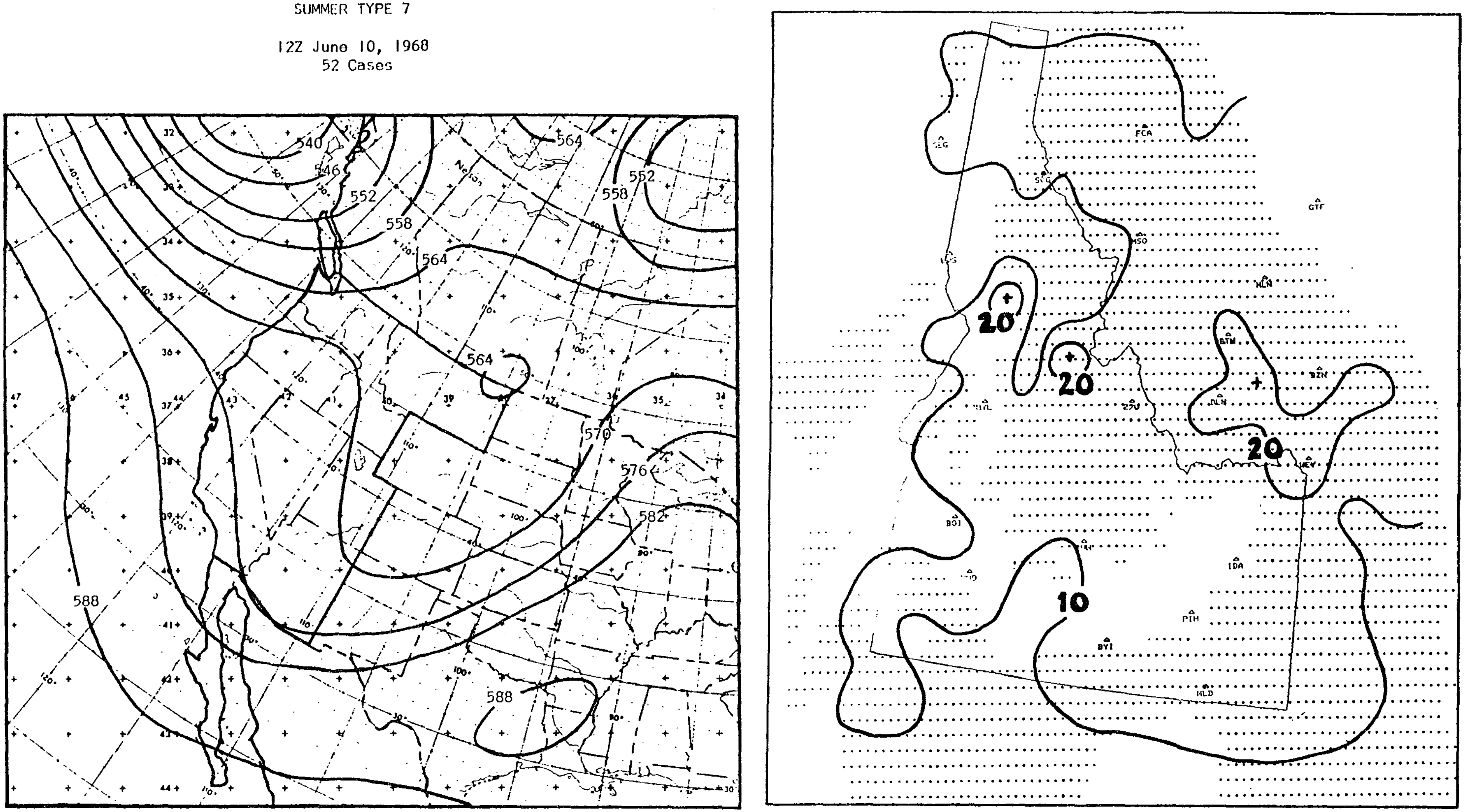
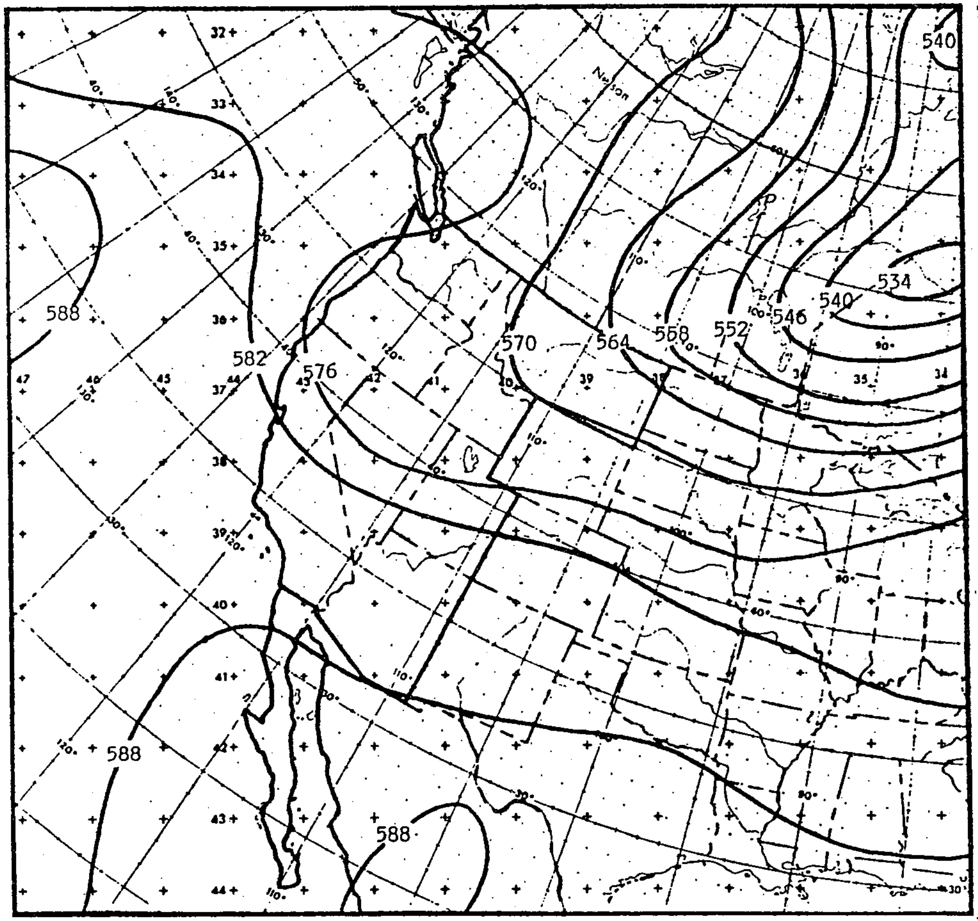


Figure 17. Summer Map Type 7 and Corresponding Percent Probabilites of Lightning during the period noon to midnight mdt. Probabilities based on 12 cases.

SUMMER TYPE 8

00Z June 23, 1967
76 Cases



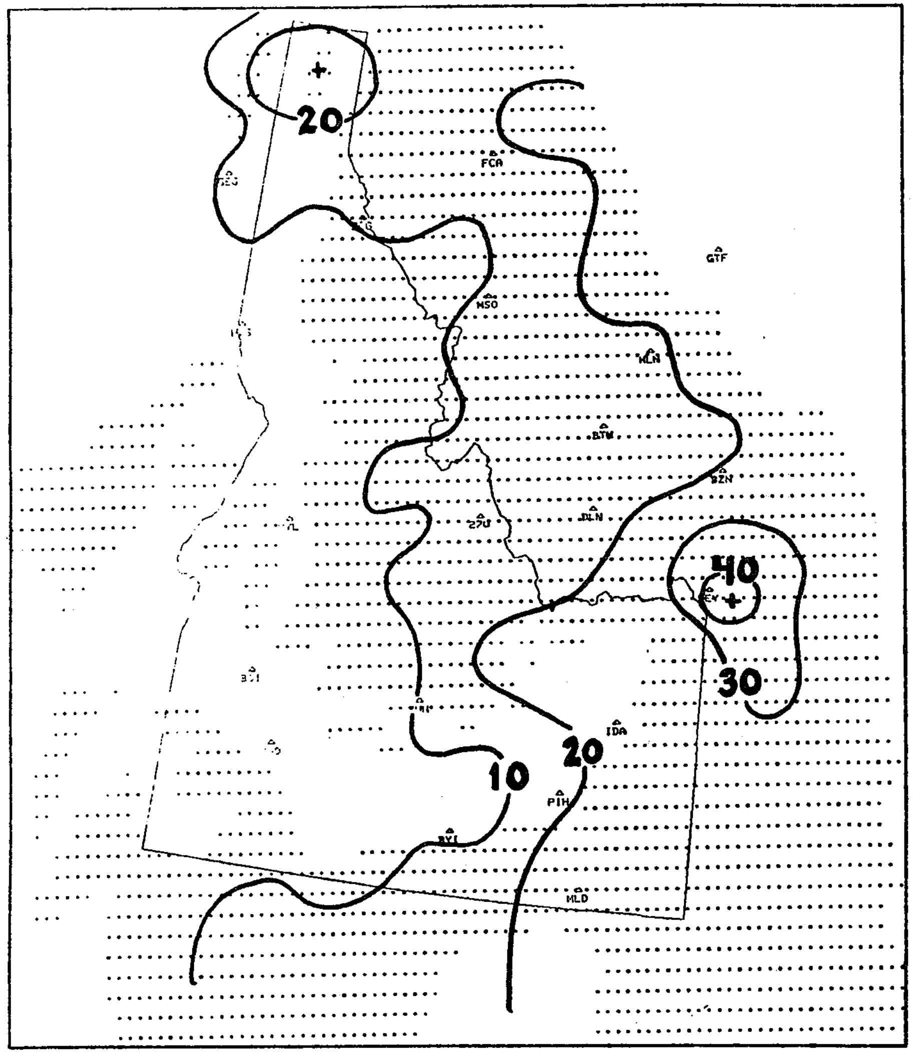
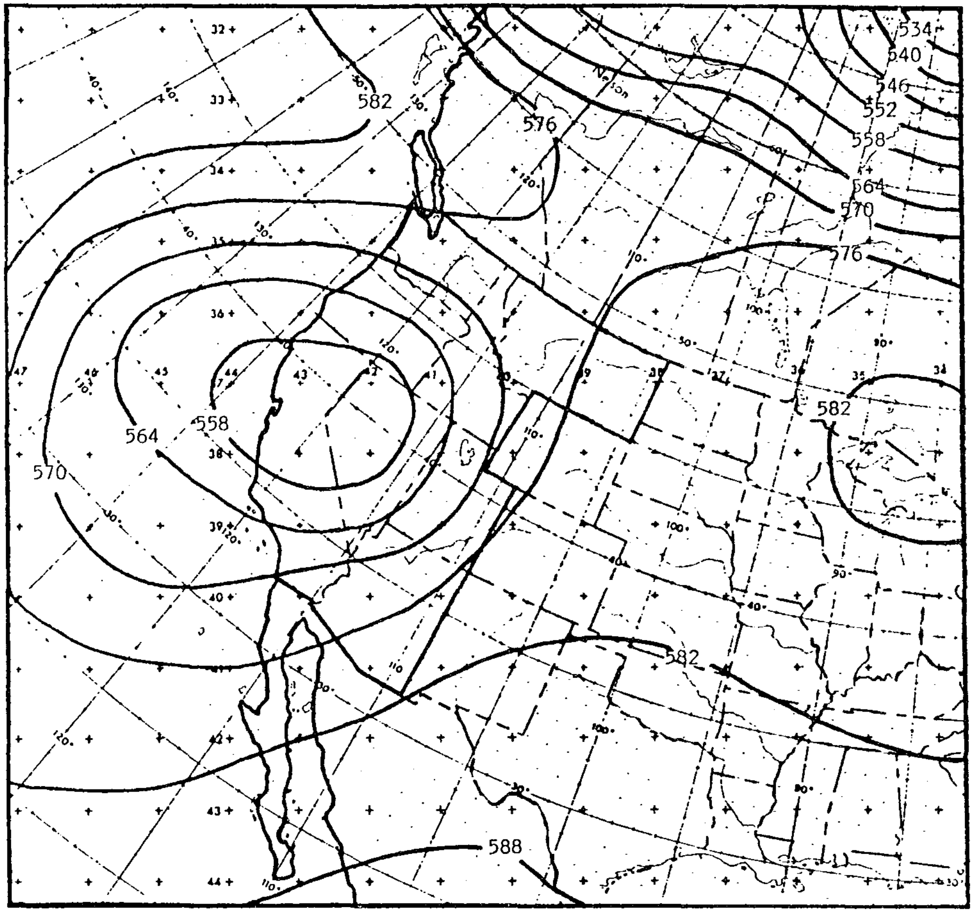


Figure 18. Summer Map Type 8 and Corresponding Percent Probabilities of Lightning during the period noon to midnight mdt. Probabilities based on 17 cases.

SUMMER TYPE 9

OOZ June 2, 1967
7 Cases



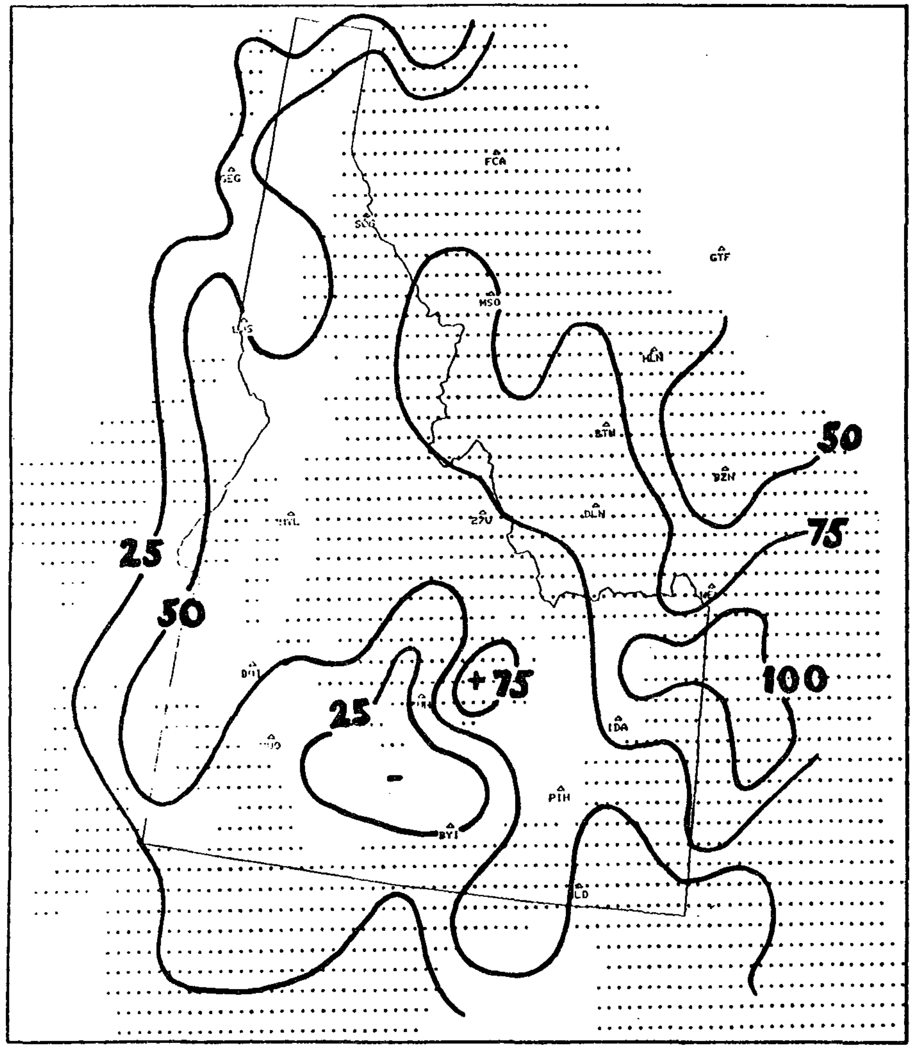


Figure 19. Summer Map Type 9 and Corresponding Percent Probabilities of Lightning during the period noon to midnight mdt. Probabilities based on 4 cases.

SUMMER TYPE 10

12Z July 12, 1964
9 Cases

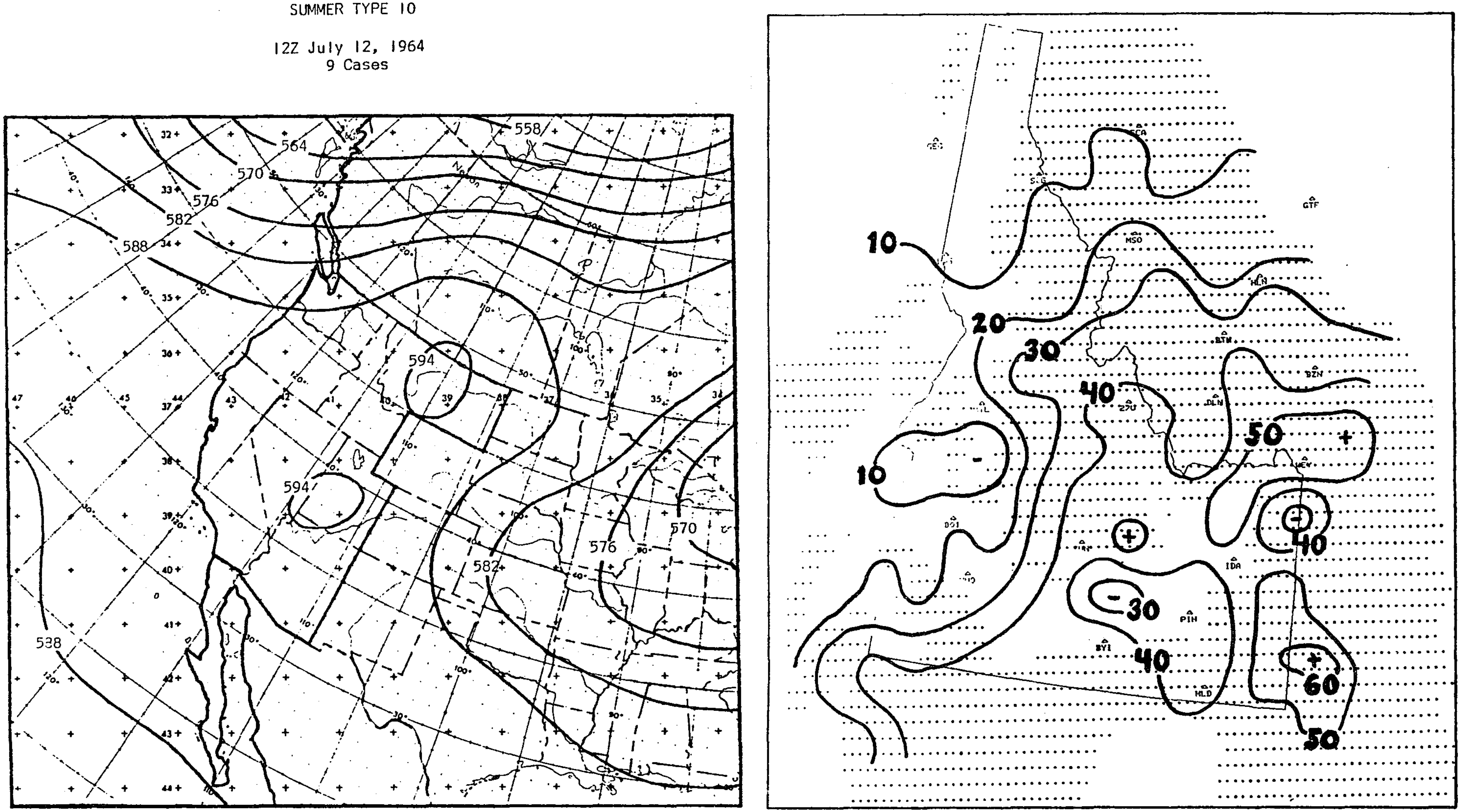


Figure 20. Summer Map Type 10 and Corresponding Percent Probabilities of Lightning during the period noon to midnight mdt. Probabilities based on 20 cases.

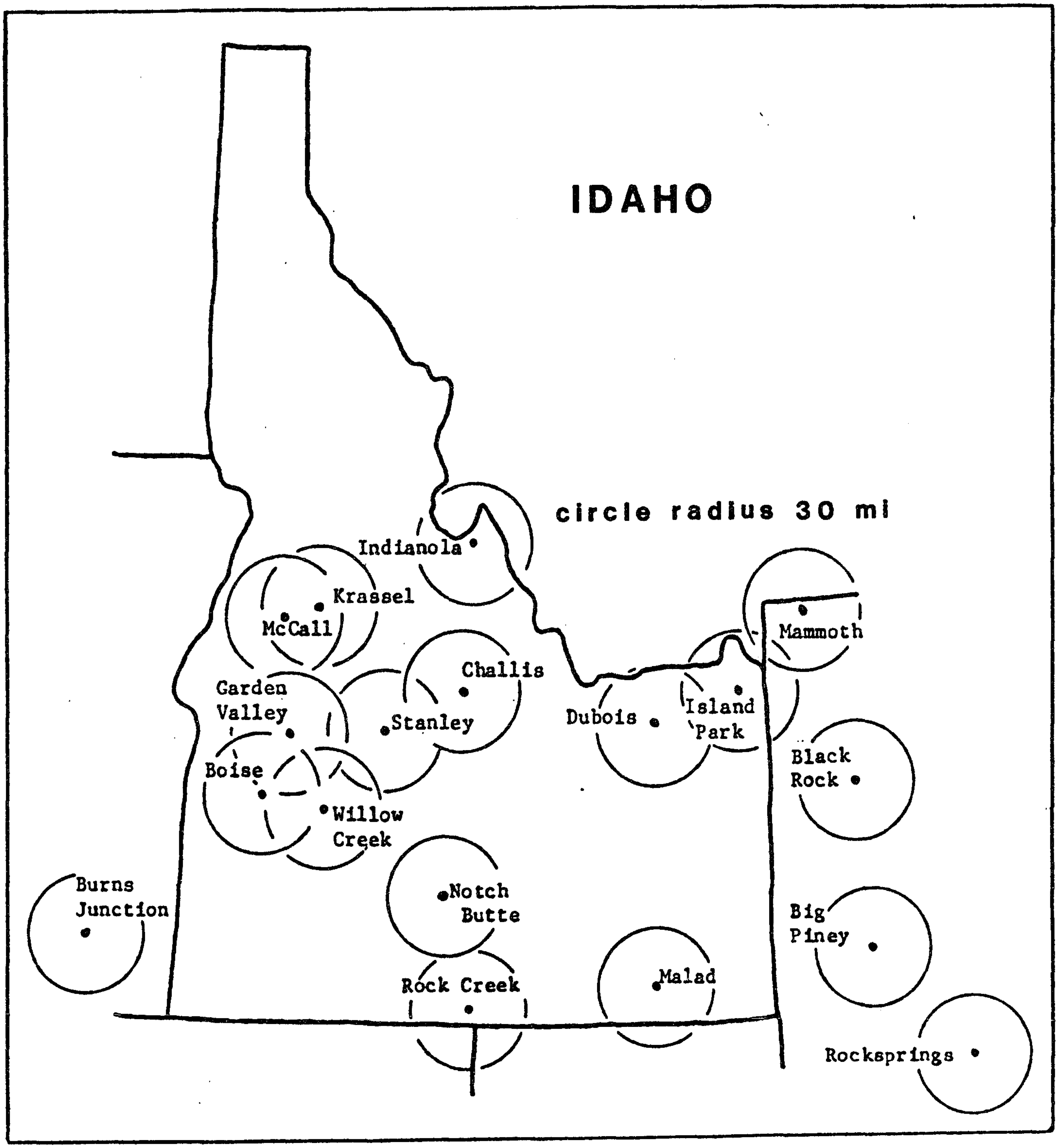


Figure 21. Map of verification stations.

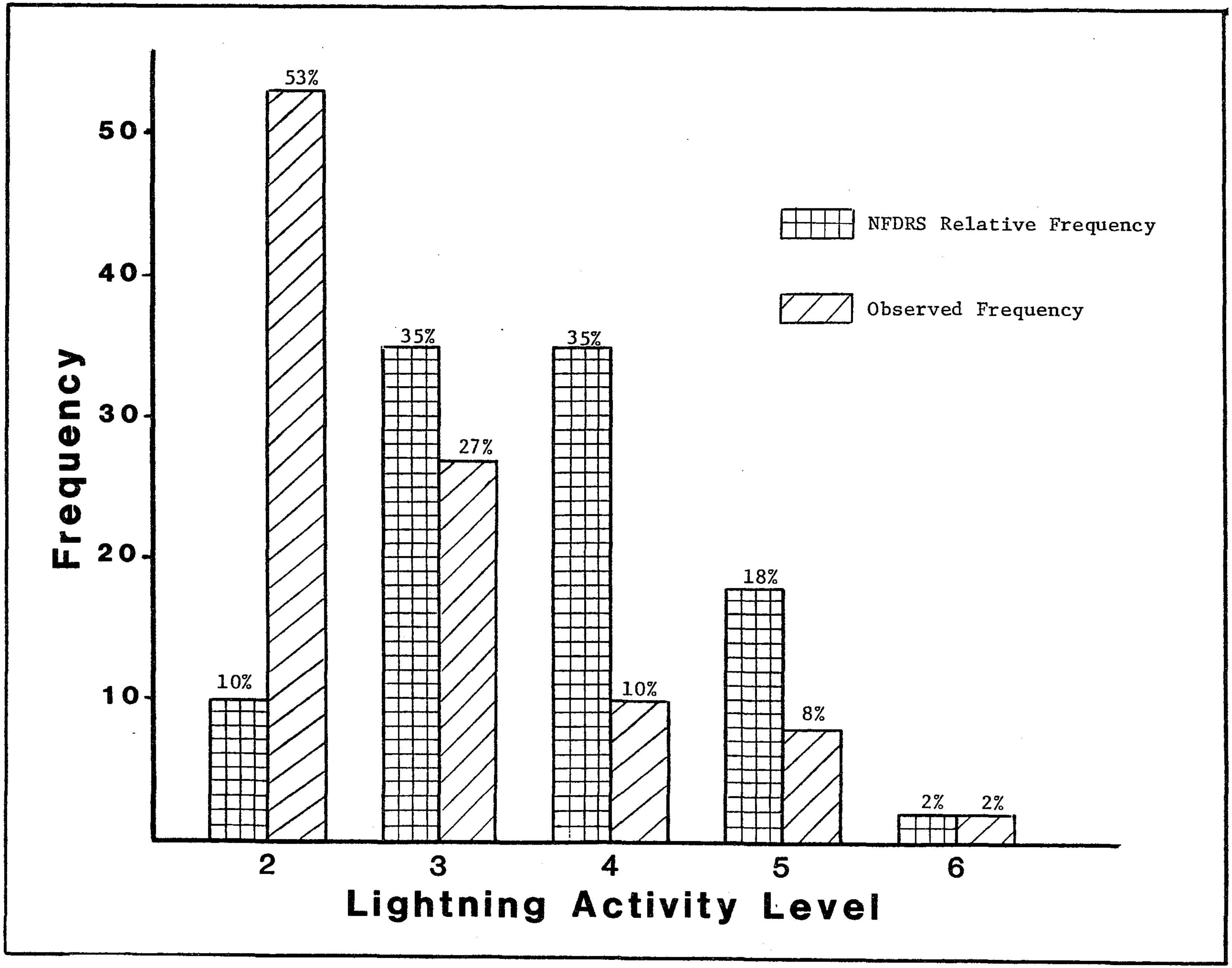


Figure 22. NFDRS Relative Frequency Distribution versus Observed Frequency Distribution.

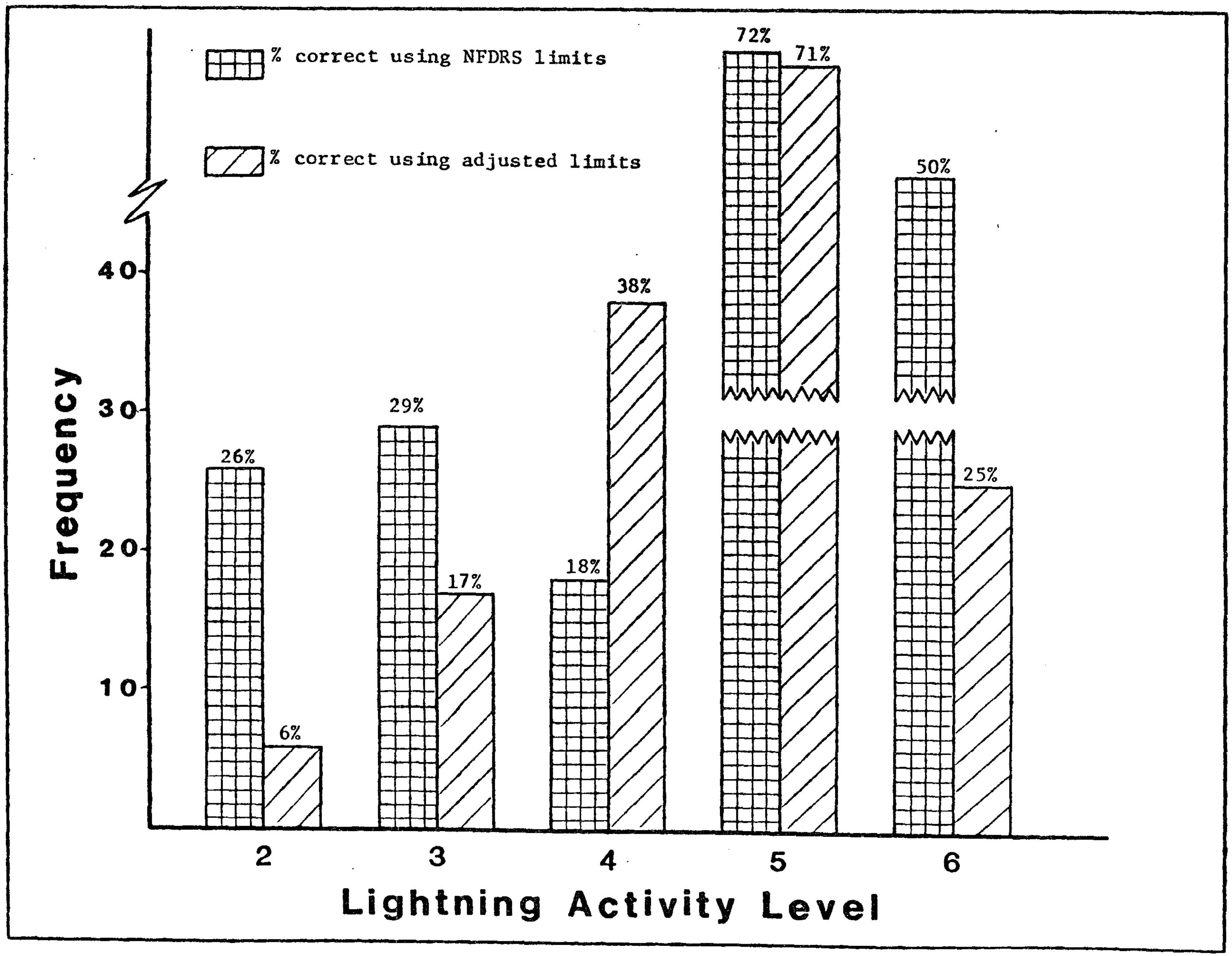


Figure 23. Frequency Distribution of Correct Observations Using NFDRS Limits versus Correct Observations Using Adjusted Limits.

TABLE 1

Frequency of Correct Categories Verified Against NFDRS
Cloud to Ground Lightning Density Limits (Fuquay)
1985-1986 Thunderstorm Season

STATION	LAL 1	LAL 2	LAL 3	LAL 4	LAL 5	LAL 6
McCall	84% (192)	18% (11)	10% (10)	50% (2)	100% (2)	NR (0)
Krassel	81% (171)	22% (9)	100% (4)	NR (0)	67% (3)	NR (0)
Garden Valley	84% (187)	32% (19)	33% (10)	0% (3)	NR (0)	0% (1)
Willow Creek	80% (190)	36% (14)	75% (4)	0% (2)	50% (2)	NR (0)
Indianola	73% (141)	26% (23)	22% (9)	NR (0)	100% (1)	NR (0)
Challis	66% (181)	25% (8)	25% (8)	40% (5)	100% (2)	100% (1)
Stanley	79% (161)	43% (14)	44% (9)	14% (7)	100% (3)	NR (0)
Burns Junction	89% (65)	26% (27)	0% (10)	NR (0)	100% (1)	0% (1)
Boise	93% (193)	33% (21)	0% (5)	0% (6)	0% (1)	67% (3)
Notch Butte	64% (143)	50% (2)	25% (4)	100% (1)	NR (0)	NR (0)
Dubois	62% (169)	31% (32)	10% (10)	25% (12)	0% (1)	NR (0)
Island Park	48% (191)	28% (18)	0% (6)	0% (5)	75% (4)	NR (0)
Rock Creek	69% (132)	0% (15)	0% (4)	34% (3)	0% (1)	NR (0)
Malad	76% (84)	12% (17)	40% (10)	22% (9)	76% (25)	50% (4)
Big Piney	56% (134)	26% (19)	22% (18)	0% (2)	83% (6)	NR (0)
Black Rock	66% (146)	14% (28)	36% (11)	0% (4)	100% (1)	50% (2)
Mammoth	61% (143)	25% (36)	31% (26)	11% (9)	25% (4)	100% (1)
Rock Springs	55% (86)	30% (63)	37% (30)	50% (2)	100% (1)	33% (3)
TOTALS	72% (2,709)	26% (376)	29% (188)	18% (72)	72% (58)	50% (16)

Total number of events in parenthesis

TABLE 2

Lightning Density Mean,
Standard Deviation and Range
for Man Observed Thunderstorm Days
by LAL Category

Station		LAL 2	LAL 3	LAL 4	LAL 5	LAL 6
McCall	Mean	91	42	44	276	NR
	S.D.	101.0	43.2	--	--	
	Range	0-277	0-127	6-82	206-346	
Krassell	Mean	52	28	NA	102	NR
	S.D.	66.5	8.7		76.9	
	Range	0-214	23-41		15-160	
Garden Valley	Mean	11	46	245	NR	199
	S.D.	13.8	73.8	216.8		--
	Range	0-47	0-242	46-476		--
Willow Creek	Mean	45	18	149	79	NR
	S.D.	89.8	12.4	--	--	
	Range	0-334	4-34	38-260	24-134	
Indianola	Mean	78	147	NR	322	NR
	S.D.	83.4	154.0		--	
	Range	0-302	3-431		--	
Challis	Mean	47	149	123	181	24
	S.D.	47.5	153.2	153.3	--	--
	Range	1-151	2-389	19-392	134-227	--
Stanley	Mean	21	42	85	137	NR
	S.D.	22.3	36.4	101.3	8.4	
	Range	0-59	1-99	4-267	132-147	
Burns Junction	Mean	22	79	NR	118	0
	S.D.	72.6	247.3		--	--
	Range	0-360	0-783		--	--
Boise	Mean	12	4	86	25	39
	S.D.	12.8	3.2	75.2	--	23.5
	Range	0-50	0-8	10-197	--	16-63
North Butte	Mean	72	126	85	NR	NR
	S.D.	100.4	83.8	--		
	Range	1-143	19-198	--		
Dubois	Mean	75	216	191	25	NR
	S.D.	121.7	179.6	186.1	--	
	Range	0-505	48-574	1-324	--	

STATION		LAL 2	LAL 3	LAL 4	LAL 5	LAL 6
Island Park	Mean	51	174	327	224	NR
	S.D.	49.9	125.7	268.1	220.7	
	Range	1-149	84-395	114-753	51-545	
Rock Creek	Mean	129	233	133	78	NR
	S.D.	222.5	156.8	75.8	--	
	Range	0-876	136-465	68-216	--	
Malad	Mean	59	46	208	426	46
	S.D.	72.6	67.3	333.1	417.1	37.7
	Range	0-206	0-190	1-1,049	14-1,659	12-82
Big Piney	Mean	130	193	335	282	NR
	S.D.	169.5	216.8	--	158	
	Range	0-476	0-709	12-657	72-478	
Black Rock	Mean	115	58	224	257	103
	S.D.	171.2	42.7	212.1	--	--
	Range	0-815	0-109	4-507	--	17-188
Mammoth	Mean	49	98	205	281	23
	S.D.	77.3	96.9	138.2	384.2	--
	Range	0-366	0-392	17-466	73-857	--
Rock Springs	Mean	84	94	106	272	52
	S.D.	113.2	90.7	--	--	71.4
	Range	0-391	4-337	60-152	--	8-134
TOTALS	Mean	72	104	177	298	57
	S.D.	114.1	136.1	197.2	321.9	64.1
	Range	0-876	0-783	1-1,049	14-1,659	8-199

TABLE 3

Number of Cloud to Ground Strikes within 2,500 mi^2 Area Per LAL Category

LAL Category	1	2	3	4	5	6
NFDRS (Fuquay) Limits	No lightning	1-10	11-50	51-100	>100	11-50
New Limits To Obtain NFDRS Frequency Distribution	No lightning	1	2-15	16-118	>118	2-15
NFDRS Relative Frequency of Thunderstorm Days per Category	No lightning	10%	35%	35%	18%	2%

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140 Influence of Cloudiness on Summertime Temperatures in the Eastern Washington Fire Weather district. James Holcomb, April 1979. (PB298674/AS)
141 Comparison of LFM and MFM Precipitation Guidance for Nevada During Doreen. Christopher Hill, April 1979. (PB298613/AS)
142 The Usefulness of Data from Mountaintop Fire Lookout Stations in Determining Atmospheric Stability. Jonathan W. Corey, April 1979. (PB298899/AS)
143 The Depth of the Marine Layer at San Diego as Related to Subsequent Cool Season Precipitation Episodes in Arizona. Ira S. Brenner, May 1979. (PB298817/AS)
144 Arizona Cool Season Climatological Surface Wind and Pressure Gradient Study. Ira S. Brenner, May 1979. (PB298900/AS)
146 The BART Experiment. Morris S. Webb, October 1979. (PB80 155112)
147 Occurrence and Distribution of Flash Floods in the Western Region. Thomas L. Dietrich, December 1979. (PB80 160344)
149 Misinterpretations of Precipitation Probability Forecasts. Allan H. Murphy, Sarah Lichtenstein, Baruch Fischhoff, and Robert L. Winkler, February 1980. (PB80 174576)
150 Annual Data and Verification Tabulation - Eastern and Central North Pacific Tropical Storms and Hurricanes 1979. Emil B. Gunther and Staff, EPHC, April 1980. (PB80 220486)
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153 An Automatic Lightning Detection System in Northern California. James E. Rea and Chris E. Fontana, June 1980. (PB80 225592)
154 Regression Equation for the Peak Wind Gust 6 to 12 Hours in Advance at Great Falls During Strong Downslope Wind Storms. Michael J. Oard, July 1980. (PB91 108367)
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158 Hydrology Practicum. Thomas Dietrich, September 1980. (PB81 134033)
159 Tropical Cyclone Effects on California. Arnold Court, October 1980. (PB81 133779)
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163 A Comparison of Two Methods for Forecasting Thunderstorms at Luke Air Force Base, Arizona. LTC Keith R. Cooley, April 1981. (PB81 225393)
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165 Annual Data and Verification Tabulation, Eastern North Pacific Tropical Storms and Hurricanes 1980. Emil B. Gunther and Staff, May 1981. (PB82 230336)
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167 ARAP User's Guide. Mark Mathewson, July 1981, revised September 1981. (PB82 196783)
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169 A Statistical-Dynamical Model for Prediction of Tropical Cyclone Motion in the Eastern North Pacific Ocean. Preston W. Leftwich, Jr., October 1981. (PB82195298)
170 An Enhanced Plotter for Surface Airways Observations. Andrew J. Spry and Jeffrey L. Anderson, October 1981. (PB82 153883)
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177 Climate of Phoenix, Arizona. Robert J. Schmidli, April 1969 (revised December 1986). (PB87 142063/AS)
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